

THE IMPORTANCE OF BASIC RESEARCH TO UNITED STATES COMPETITIVENESS

HEARING BEFORE THE SUBCOMMITTEE ON TECHNOLOGY, INNOVATION, AND COMPETITIVENESS OF THE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE ONE HUNDRED NINTH CONGRESS

SECOND SESSION

MARCH 29, 2006

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED NINTH CONGRESS

SECOND SESSION

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THE IMPORTANCE OF BASIC RESEARCH TO UNITED STATES COMPETITIVENESS

WEDNESDAY, MARCH 29, 2006

U.S. SENATE,
SUBCOMMITTEE ON TECHNOLOGY, INNOVATION, AND
COMPETITIVENESS,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 10:06 a.m. in room SD-562, Dirksen Senate Office Building, Hon. John Ensign, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. JOHN ENSIGN, U.S. SENATOR FROM NEVADA

Senator ENSIGN. Good morning. Welcome to today's hearing on the importance of basic research to United States' competitiveness.

As the world becomes dramatically more interconnected and competitive, the United States must lead the world's innovation. Innovation fosters new ideas, technologies, and processes that lead to better jobs, higher wages, and a higher standard of living.

While innovation is key to the future global competitiveness of the United States, basic research is the key to future innovation. Basic research is research that is conducted to understand the basic underpinnings of science, the world around us, and how it all operates. It is very broadly-based research. Although basic research is not specifically directed toward solving any one particular problem, it is essential research for society.

Over the past 25 years, basic research supported by the National Science Foundation in chemistry, physics, nanotechnology, semiconductor manufacturing, and other fields has brought about revolutionary technological advances. For example, basic research funded by NSF in the 1980s and early 1990s on laser crystalization of amorphous silicon enabled today's popular flat-panel displays for computers and TVs. Basic research conducted in the 1980s on hot electron injection in thin insulator films facilitated the creation today of digital cameras, pocket memory sticks, and iPods. I challenge a lot of other Senators to pronounce some of these things.

[Laughter.]

Senator ENSIGN. The World Wide Web, magnetic resonance imaging, bar codes, airbags, global-positioning devices, and fiber optics technology all emerged through basic research projects that received Federal Government funding. In every case, research investment by the Federal Government was necessary to proceed to the

point at which the private-sector recognized a potentially-marketable product and invested in its further development.

I believe that increased funding of basic research at the National Science Foundation, the National Institutes of Standards and Technology, and other Federal agencies should be a national priority.

I am a fiscal conservative, but Federal investment in basic research remains vital, because basic research is very important to the long-term economic vitality of the United States, and corporations and other participants in the private-sector are not well situated to fund basic research.

Experts vary in their assessment of the exact rates-of-return on basic research. There is broad agreement, however, that basic research in science, technology, engineering, and mathematics makes a critical contribution to the growth of the United States' economy. Especially given increased competition from nations like India and China, failure to support NSF and basic research creates a serious risk for our Nation. U.S. competitiveness in global markets and the creation of good jobs at home rely increasingly on the cutting-edge innovation that stems from high-risk, high-reward basic research. U.S. technological leadership, innovation, and jobs of tomorrow require a commitment to basic research funding today.

We are pleased to have two panels of witnesses here to testify on the importance of basic research to United States' competitiveness. The record will remain open for 7 days for Senators to submit questions or statements, and any Senators that wish to make statements for the record will be allowed to do so without objection.

On our first panel we will have three witnesses. Our first witness will be Dr. John Marburger III. Dr. Marburger is the Director of the Office of Science and Technology Policy. After Dr. Marburger's testimony, our second witness will be Dr. Arden Bement. Dr. Bement is the Director of the National Science Foundation. After Dr. Bement's testimony, our third witness on this panel will be Dr. William Jeffrey. Dr. Jeffrey is the Director of the National Institute of Standards and Technology.

I welcome all three of you, and look forward to your testimony. If you could keep your testimony to around 5 minutes in length, it would be helpful. Please summarize where appropriate. Your full statements will be made part of the record, but if you can summarize your main points we can save as much time as possible for a good discussion on this important topic. I always like subcommittee hearings, because we end up having a lot more give and take. I always enjoy the subcommittee hearings a great deal. I look forward to the discussion today.

Doctor Marburger?

**STATEMENT OF DR. JOHN MARBURGER III, DIRECTOR,
OFFICE OF SCIENCE AND TECHNOLOGY POLICY,
EXECUTIVE OFFICE OF THE PRESIDENT**

Dr. MARBURGER. Great. Thank you very much. Chairman Ensign, the Administration greatly appreciates the efforts of the Senate Commerce Committee, and your work, in particular, to highlight the importance and priority of federally-funded basic research, which has resulted in good outcomes for our Nation.

I do have a longer written testimony, and I'll try to summarize as quickly as possible.

President Bush introduced the American Competitiveness Initiative in his State of the Union Address to ensure America's continued economic competitiveness through innovation based on technologies that have their basis in scientific research. This initiative occurs in the context of a budget that aims to reduce the deficit by, among other things, reducing non-Department of Defense, non-Homeland Security discretionary spending by almost one-half of one percent. And, consequently, this budget is about priorities: winning the war on terrorism, securing the homeland; these are necessarily urgent priorities. But investing in America's future competitiveness through research and development is also of critical importance to our Nation.

The President is seeking a 2 percent increase in nondefense R&D within a declining overall nondefense budget. At a record \$59 billion, the nondefense R&D budget is up \$1.1 billion in this year's request. The President's budgets have always supported research and development at impressive levels. I've brought a display here. I like to show this, though, the blue mountain here to indicate Federal nondefense spending and how it's soared in this Administration.

The centerpiece of the American Competitiveness Initiative is the President's proposal to double funding over 10 years for key agencies that sponsor basic research in physical sciences and engineering that is likely to have a high impact on future economic competitiveness. For FY07, the President is requesting \$6 billion for the National Science Foundation, \$4.1 billion for Department of Energy's Office of Science, and \$535 million for the Department of Commerce's National Institute of Standards and Technology core programs. New funds for these agencies total \$910 million, or a 9.3 percent increase, for these agencies.

The President's budget also prioritizes similarly high-leverage basic and applied research at the Department of Defense in 2007 by requesting additional funding for them.

Annual increases for these agencies would average roughly 7 percent to achieve doubling in 10 years, which amounts to a total of \$50 billion in new investments. And we have another display that indicates how the money ramps up for these agencies.

The ACI also identifies priority strategies in education, workforce training and integration practices, and Members of Congress, including many on this committee, have helped to bring attention to the need for such strategies. And many other groups also deserve credit for highlighting the importance of investment in these areas, including the President's Council of Advisors on Science and Technology (PCAST), Council on Competitiveness, and the National Academy of Sciences.

While the Administration designed the American Competitiveness Initiative to prioritize and advance scientific endeavors with the highest marginal value for future economic competitiveness—and, Mr. Chairman, your opening remarks summarized the value of this and the conclusions of economists that indicate that there is an important return to the public for these investments, so I'm not going to go further into this; my colleagues on today's panel can

offer many examples of the contributions their agencies have made that support current technologies that have changed our way of life—this Initiative, the ACI, directs funds to agencies with well-defined programs with a clear relevance to future economic competitiveness. It does not attempt to expand support for every area of basic science, nor even for every field within the physical sciences. It seeks the maximum impact with a minimum of bureaucratic apparatus, taking advantage of programs and processes already in place and working well.

In view of the many proposals for enhancing America's future competitiveness, the challenge now is to retain a focus on the most important actions we must take, and avoid diffusing the impact of the resources at our disposal. This Initiative resists the impulse to act on every good idea. And our plea is to reject unnecessary new programs and bureaucratic burdens and to keep the Initiative clean and simple.

President Bush has also called upon Congress to ensure that funds provided to the agencies under this Initiative are free of earmarks.

This Initiative enhances fundamental research in key areas of the physical sciences and engineering, similar to the emphasis on biomedical research over the last decade. A broad consensus exists that these are the most important areas for generating additional breakthroughs that drive the economy, and these are also the areas of Federal R&D portfolio most in need of additional resources.

I look forward to working with you and others in Congress to ensure that these critical areas receive the support they need to keep our Nation strong.

Thank you.

[The prepared statement of Dr. Marburger follows:]

PREPARED STATEMENT OF DR. JOHN MARBURGER III, DIRECTOR, OFFICE OF SCIENCE
AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Chairman Ensign, Ranking Minority Member Kerry, and members of the Subcommittee, I am pleased to appear before you today to discuss "The Importance of Basic Research to United States' Competitiveness," which is embodied in the President's American Competitiveness Initiative. The Administration greatly appreciates the efforts of the Senate Commerce Committee—and your work in particular Mr. Chairman—to highlight the importance and priority of federally-funded basic research, which has resulted in good outcomes for the Nation.

One of these outcomes has been widespread recognition of the critical role the science and technology enterprise plays as the foundation for the United States' economic competitiveness. This is a message President Bush has elevated through his American Competitiveness Initiative (ACI), which he announced in his State of the Union Address and has repeated in many speeches and remarks since then.

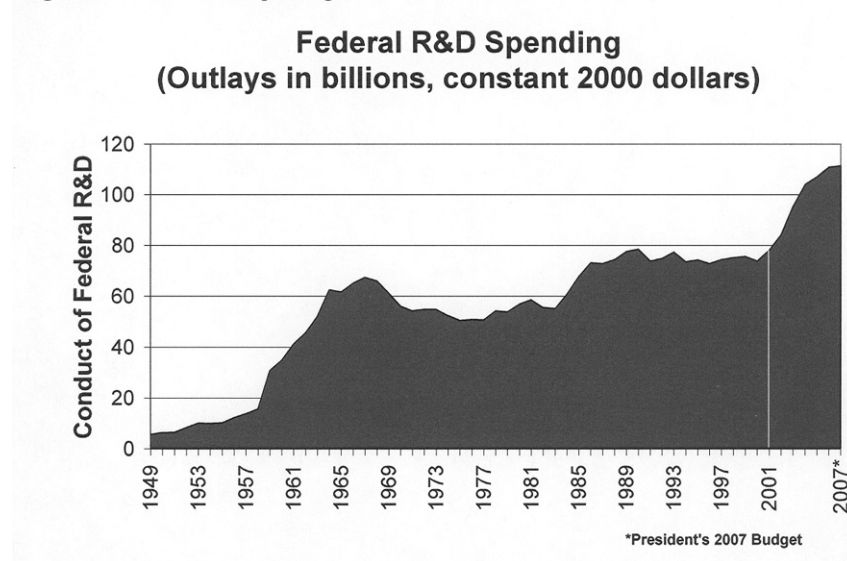
I will discuss the ACI in a moment, and its focus on basic research, but it is important first to place it in the context of this year's budget.

President Bush has made it clear that his top budget priority is to cut the deficit in half by 2009, by continuing this Administration's strong pro-growth economic policies and limiting the growth in Federal spending. The President's FY 2007 budget does what is required to achieve this goal by reducing non-Department of Defense, non-Homeland Security discretionary spending by almost one-half of one percent. Consequently, this budget is about priorities. And while winning the War on Terror and securing the homeland are necessarily at the top, investing in America's future competitiveness through research and development is also of critical importance to this Administration. That is why the President is seeking a 2 percent increase in non-defense R&D within a declining overall non-defense budget. Under the President's 2007 budget, R&D is 14.3 percent of non-defense discretionary budget

authority, compared to 13.7 percent in 2001 when the President took office. At a record \$59 billion, non-defense R&D is up \$1.1 billion in this year's request.

Given the overall environment of fiscal discipline, it is notable that President Bush once again proposes a record R&D budget—over \$137 billion, 2.6 percent, or \$3.4 billion, more than this year's funding level. This represents an increase of more than 50 percent during this Administration (*Figure 1*). Funding proposed for the category of Basic Research is \$28.2 billion in 2007, up from \$21.3 billion in 2001—a 32 percent increase. While this year research received prominence in the President's State of the Union address and the American Competitiveness Initiative, it is an important fact that the President's budgets have consistently supported research and development at levels commensurate with other major priorities throughout this Administration. Real five-year growth in the conduct of the R&D budget has exceeded 40 percent for each of the last 2 years, the first time five-year inflation adjusted R&D outlays have topped 40 percent since 1967 and the Apollo era.

Figure 1. Federal R&D Spending in Constant 2000 Dollars.



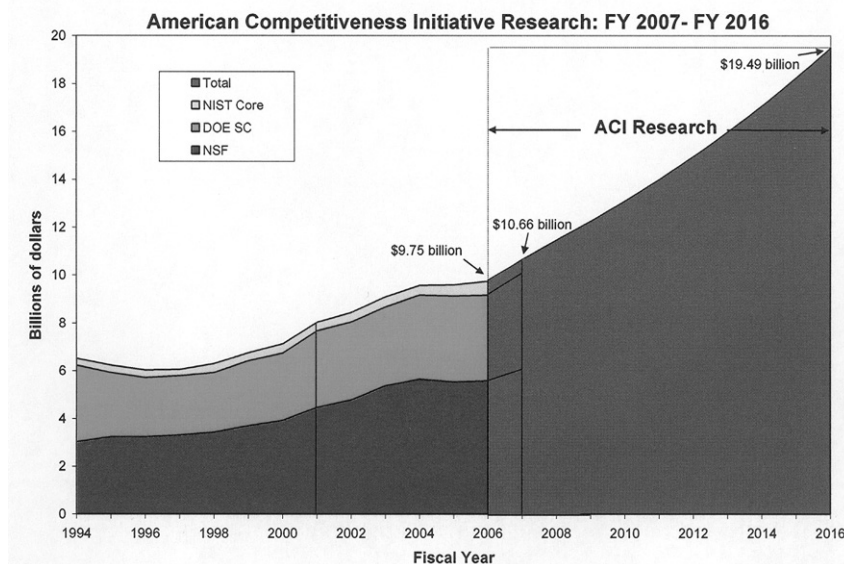
American Competitiveness Initiative (ACI)

American economic strength and national security depend on our Nation's rich tradition of innovation. To assure our future technological leadership and take full advantage of America's current technological dominance in the world, President Bush launched the American Competitiveness Initiative (ACI). The ACI commits \$5.9 billion in FY 2007, and more than \$136 billion over 10 years, to increase investments in R&D, strengthen education, and encourage entrepreneurship and innovation.

The centerpiece of the American Competitiveness Initiative is the President's proposal to double, over 10 years, funding for key agencies that sponsor basic research in the physical sciences and engineering that is likely to have high impact on future economic competitiveness. Certain areas within the physical sciences not only advance fundamental knowledge, but also generate new technologies that are broadly useful in society as well as in many other fields of science, such as nanotechnology and supercomputing. President Bush seeks to strengthen Federal investments in these priority areas by making landmark initial investments in 2007 in three key, innovation-enabling research agencies: \$6 billion for the National Science Foundation (NSF); \$4.1 billion for the Department of Energy's Office of Science (DOE SC); and \$535 million for the Department of Commerce's National Institute of Standards and Technology (NIST) core programs. The President's budget also prioritizes the similarly high-leverage basic and applied research at the Department of Defense in 2007 by requesting \$5.9 billion, \$442 million (8 percent) more than last year's request.

In 2007, the ACI proposes overall funding increases for NSF, DOE SC and NIST core of \$910 million, or 9.3 percent (*Figure 2*). Overall annual increases for these agencies will average roughly 7 percent to achieve doubling in 10 years. This amounts to a total of \$50 billion in new investments in high-leverage, innovation-enabling research that will underpin and complement shorter-term and mission-oriented R&D performed by other agencies and the private-sector. To encourage private investment in innovation to be equally bold, President Bush continues to propose permanent extension of the R&D tax credit and supports steps to modernize it to make it even more effective.

Figure 2. ACI Research: FY 2007 – FY 2016.



While the President has given funding priority to specific physical science and engineering programs in previous budgets, through such coordinated initiatives as the Networking Information Technology Research and Development (NITRD) program, the National Nanotechnology Initiative (NNI) and others, the ACI recognizes the enabling role of broader areas within the physical sciences in contributing to national competitiveness, and proposes a significant ramping-up of funding for selected agencies over a sustained budget period. Of course national competitiveness depends on more than research. The ACI identifies similar selected priority strategies in education, workforce training, and immigration practices as well. Members of Congress—including many on this committee—have helped to bring attention to the need for such strategies in our national discourse. Many other groups also deserve credit for highlighting the importance of investment in these areas, including the President's Council of Advisors on Science and Technology (PCAST), the Council on Competitiveness and the National Academy of Sciences. It is rare that so many different organizations speak the same language. I am optimistic that with your help and the support of the scientific community, we can provide funding for the ACI.

Why Basic Research?

The Administration designed the American Competitiveness Initiative to prioritize and advance those scientific endeavors with the highest marginal value for future economic competitiveness. Public-sector research funding that typically has the highest marginal value is not directed toward specific products or technologies, but rather fosters the generation of fundamental knowledge that has significant spill-over benefits that cannot be captured through intellectual property protection. Economists have concluded that such research can generate large public returns but does not usually provide a direct profitable return for private-sector performers.

The economic payoffs of such research often come in the form of process and product innovations that reduce the costs of production, lower product prices, and result in new and better products and services. This research can even spawn entire new industries. The economic return shows up in economic statistics through increases

in firms' output, aggregate GDP, and "total factor" productivity—that is, the amount of economic output that we can get from a given amount of labor, capital, energy, and material inputs. Consumers ultimately benefit from having access to less expensive, higher quality, and more useful products and services, as well as from earnings accruing to innovative companies. Put another way, basic research raises the standard of living.

Economic research finds private rates-of-return to R&D in the range of 20 to 30 percent, reflecting the returns received directly by the innovator. These private returns to R&D are considerably higher than the roughly 10 percent average return on other types of investments, attributable to the considerable risk and uncertainty associated with the technical and commercial success of R&D projects, as well as the depreciation of innovation value over time. Total social rates-of-return to R&D—including the "spillover benefits" to firms and consumers that did not conduct the original research—are typically estimated to be much higher than the private returns, ranging from 30 to 80 percent.

Innovation spillovers flow through at least three distinct channels. First, "knowledge spillovers" occur because knowledge created by one firm cannot typically be contained within that firm, and thereby creates value for other firms and other firms' customers. Second, "market spillovers" occur when an innovation creates benefits for consumers and non-innovating firms that are not fully captured by the innovating firm due to competition and other market forces. Third, because the profitability of a set of interrelated and interdependent technologies may depend on achieving a critical mass of success, each firm pursuing one or more of these related technologies creates economic benefits or "network spillovers" for other firms and their customers. Technical standards often have an important role to play in the context of markets with significant network effects.

The location of innovation also matters in that spillovers, at least to some degree, tend to spread from a geographical locus. For example, flows of knowledge to U.S. innovators are more likely to come first from the United States than from abroad. Globalized information flows reduce the impact of the distance factor, but it remains significant in explaining technology diffusion and spillover effects. The comparative advantage of the high-cost countries of North America and Western Europe is increasingly based on knowledge-driven innovative activity. Thus, the location of knowledge-based activity matters for innovation and ultimately comparative advantage.

The Council on Competitiveness summarizes the importance of basic research in a "calculus of innovation": (1) Knowledge drives innovation; (2) Innovation drives productivity; and (3) Productivity drives our economic growth.

Why Physical Sciences and Engineering?

Certain areas of physical science and engineering research are strongly correlated with innovation and economic growth. The ACI priority agencies each have special features that merit significant attention even in a period of budgetary constraint.

The *DOE Office of Science (SC)* is the Nation's largest sponsor of physical science research. It supports physical science capabilities and infrastructure used by a large number of investigators in nearly every field of science, and particularly those related to economically-significant innovations (*e.g.*, nano-, bio-, info-tech, energy, new materials and processes). Within DOE-SC, the new funding from ACI is expected to improve facilities and support approximately 2,600 new researchers.

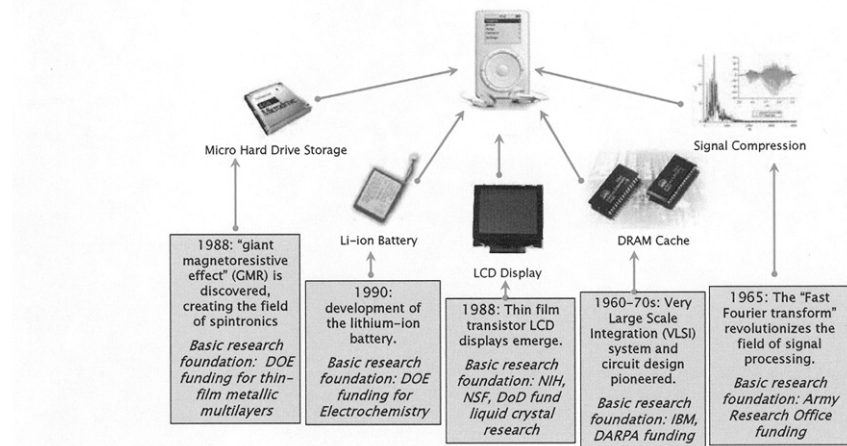
The *National Science Foundation (NSF)* is the primary source of support for academic research in the physical sciences. It funds potentially-transformative basic research in areas such as nanotechnology, information technology, physics, materials science, and engineering. The NSF is well-regarded for management of funding through competitive, peer-reviewed processes. The NSF funding derived from the ACI is expected to support as many as 500 more research grants in 2007, and provide opportunities for upwards of 6,400 additional scientists, students, post-doctoral fellows and technicians to contribute to the innovation enterprise.

The *DOC National Institute of Standards and Technology* may be the highest-leverage Federal research agency supporting economically-significant innovations. Its world-class team of scientists, recognized by three Nobel prizes during the past decade, plays a critical role in supporting standards development activities that are essential for the commercial viability of new technology. In FY 2007, NIST will seek to focus 3,900 scientists and engineers from government, industry and universities—an increase of 600 researchers over 2006—on meet-

ing the Nation's most urgent measurement science and standards needs to speed innovation and improve U.S. competitiveness.

While the very nature of basic research limits our ability to predict what inventions and technologies will one day arise from investments in these agencies, a look at the past value of basic research provides a sense of what we might expect in the future. In recent decades, fundamental research advances have provided society with technology that has enabled microchips, personal computers, the Internet, balloon catheters, bar codes, fiberoptics, e-mail systems, hearing aids, air bags and automated teller machines, to name just a few quality-of-life improving and standard-of-living raising changes. These inventions can usually be traced back to Federal support for basic research. The development of the portable MP3 player is a timely and useful example of this connection (Figure 3).

Figure 3. Impact of Basic Research on Innovation



The development of MP3 technologies illustrates the unexpected benefits of basic research. In 1965, a hand-sized storage and playback device that would hold 15,000 recorded songs was the stuff of science fiction. Even simple hand-held calculators were rare and expensive at that time. Research funded by the Department of Defense, the National Science Foundation, the National Institutes of Health, the Department of Energy, and the National Institute of Standards and Technology contributed to the breakthrough technologies of magnetic storage drives, lithium-ion batteries, and the liquid crystal display, which came together in the development of MP3 devices. The device itself is innovative, but it built upon a broad platform of component technologies, each derived from fundamental studies in physical science, mathematics, and engineering.

The inventions and innovations of the future that will be advanced in terms of quality, quantity and timeliness by ACI are in the areas of nano-, bio-, and information technology and manufacturing, solar, nuclear and hydrogen energy, new materials and processes. Specific innovation-enabling potential outcomes of ACI basic research include:

- world-leading capability and capacity in nanofabrication and nano-manufacturing—a determinant industry of the future.
- necessary next-generation investigation tools to study materials at the nanoscale.
- world-leading, high-end computing capacity (petascale) and capability (design) and advanced networking as fast as possible to address grand challenges.
- overcoming technical barriers for quantum information processing.
- new technologies for hydrogen, nuclear and solar energy through novel new basic research approaches in materials science.
- addressing gaps and needs in cyber security to lead the world in information, knowledge and intellectual property protection and control.
- basic research on sensor and detection capabilities (e.g., for Improvised Explosive Devices) which can also lead to world-leading automation and control technologies.
- solving fundamental technical problems in the application of biometrics.

- develop manufacturing standards for unprecedented technologies for the supply chain.
- improving building standards in high-risk areas (*e.g.*, hurricane and earthquake-prone regions).
- responding to international standards challenges which affect U.S. competitiveness.

Maximizing the Effectiveness of Research Funding

The widespread support for actions such as proposed in the President's American Competitiveness Initiative is deeply gratifying to us in government who labor on behalf of science and engineering. I want to take this opportunity to point out that the recommendations of the many organizations that have spoken out on the need for such an Initiative express priorities for action in a very broad and general way. When money is tight, and many needs compete for finite resources, it is necessary to define priorities with much more specificity than these otherwise excellent advocacy reports. The ACI responds to this need to prioritize. It attempts to direct funds to agencies with well-defined programs with a clear relevance to future economic competitiveness. It does not attempt to expand support for every area of basic science, nor even for every field within the physical sciences. It seeks the maximum impact with the minimum of bureaucratic apparatus, taking advantage of programs and processes already in place and working well.

In view of the many proposals for enhancing America's future competitiveness, the challenge now is to retain a focus on the most important actions we must take, and avoid diffusing the impact of the resources at our disposal. The ACI resists the impulse to act on every good idea. Our plea is to reject unnecessary new programs and bureaucratic burdens and to keep the Initiative "clean and simple."

To that end, President Bush has called upon Congress to ensure that funds provided to the agencies under the American Competitiveness Initiative are free of earmarks. As we discuss the importance of pursuing the best science to contribute to U.S. competitiveness, I hope the Congress will join with us to encourage competition for research funding by rejecting research earmarks in the FY 2007 appropriations process.

Conclusion

America currently spends one and a half times as much on federally-funded research and development as Europe, and three times as much as Japan, the next largest investor. Our scientists collectively have the best laboratories in the world, the most extensive infrastructure supporting research, the greatest opportunities to pursue novel lines of investigation, and the most freedom to turn their discoveries into profitable ventures if they are inclined to do so. We lead not only in science, but also in the productivity, innovation, and technological prowess that is necessary to translate science into economically-significant products that enhance the quality of life for all people.

Nonetheless, other nations seek to achieve the quality of life for their own large populations that many Americans take for granted. These nations aim to close the gap by emulating our successful model—devoting increased resources to their scientific and technological enterprises in an effort to better compete with the U.S. on the global economic stage. To ensure that their success does not diminish our own, we must act now with the confidence to which our leadership position entitles us to build upon our strength.

The President's FY 2007 budget will sustain this leadership and maintain science and technology capabilities that are the envy of the world. The proposed ACI basic research investments and R&D tax credit changes directly address America's innovation challenges. These are sound in terms of science and technology policy, and consistent with the broader Administration economic policy to foster and maximize America's long-term growth potential. ACI refocuses the Federal R&D portfolio by placing increased emphasis on fundamental research in key areas of the physical sciences and engineering, similar to the increases in fundamental biomedical research over the last decade. A broad consensus exists that these are the most important areas for generating additional breakthroughs that drive the economy, and these are also the areas of the Federal R&D portfolio most in need of additional resources. They deserve priority in the FY 2007 budget over all other R&D, except perhaps for selected programs supporting national and homeland security.

I would be pleased to respond to questions.

Senator ENSIGN. Thank you, Dr. Marburger. Dr. Bement?

**STATEMENT OF DR. ARDEN L. BEMENT, JR., DIRECTOR,
NATIONAL SCIENCE FOUNDATION**

Dr. BEMENT. Chairman Ensign, I'm delighted to appear before you for the first time.

For over 50 years, NSF has been a strong steward of the Nation's scientific discovery and innovation process. The President recognized this when he designated NSF to be a key participant in the American Competitiveness Initiative.

Despite its small size, NSF has an extraordinary impact on science and engineering knowledge and capacity. While NSF represents only 4 percent of the total Federal budget for research and development, it accounts for 50 percent of non-life sciences basic research at academic institutions. In fact, NSF is the only Federal agency that supports all fields of science and engineering research and the educational programs that sustain them across generations.

We provide funding to the best of the best. Of the 504 U.S. individuals who have received the Nobel Prize since NSF first awarded research grants in 1952, 166, or 33 percent, received NSF funding at some point in their careers. NSF-funded results permeate our society, from Doppler radar to MRI scans, from the Internet to nanotechnology, from Google to barcodes, and from computer-aided design systems to tissue engineering. NSF investments have had a profound effect on our quality of life and on American competitiveness. Just these examples have added hundreds of billions of dollars to the U.S. economy over the past 15 years.

As we know, investments in fundamental research often yield unexpected benefits. One example I like to use is NSF support for complex auction structures, through abstract auction theory and experimental economics. NSF-supported researchers provided the FCC with its current system for apportioning the airwaves. Since their inception in 1994, FCC spectrum auctions, based on game theory, have netted over \$45 billion in revenue for the Federal Government and more than \$200 billion in worldwide revenues. Although the payoff was unexpected at the time, it is many times greater than the total investment NSF has made in the social and behavioral sciences.

I would like to point out just a few other recently funded, less well-known developments with equal promise, most of which illustrate the accelerating convergence between the physical and health sciences.

For example, the world's first ultrafast, ultra-accurate laser scalpel was developed by a physicist and ophthalmologist at NSF's Center for Ultrafast Optical Science. Called "InterLase," it replaces the old LASIK system that required a blade.

Penelope, a robot surgical assistant, made her operating room debut last June. Completely autonomous, it delivered and retrieved instruments during an operation at Columbia University Medical Center.

An NSF-funded researcher has developed specially-coated nanotubes that can be painlessly implanted under the skin. They fluoresce in direct proportion to glucose levels in the blood, potentially eliminating the need for glucose testing using needles.

Both the artificial retina to assist the blind to see and the new ultra-sensitive artificial cochlea to assist the hearing-impaired to hear were developed with NSF support. The cochlea replacement is expected to be far cheaper and easier to manufacture than today's replacement devices.

Finally, researchers funded by NSF have engineered a biofiltration system that produces hydrogen gas while cleaning waste water. The invention won *Popular Mechanics'* Breakthrough Award last year.

Mr. Chairman, I hope these brief examples of what basic research can do to help U.S. competitiveness are compelling. But it's important to note that in our efforts to advance the frontier, we also aim to enhance development of the Nation's STEM talent pool by integrating research and education. The world-class scientists, technologists, engineers, and mathematicians trained through NSF-sponsored research transfer new scientific and engineering concepts from universities directly to the entrepreneurial sector as they enter the workforce. This capability is a strong suit in U.S. competitiveness and one of NSF's greatest contributions to the Nation's innovation system.

Another significant contribution comes from NSF's coupling with industry in the private-sector. NSF's research centers programs, such as our Engineering Research Centers and Science and Technology Centers, directly invite private-sector partners to engage in and sponsor related cutting-edge research that can lead to high-leverage innovations.

Furthermore, NSF couples investments in our Small Business Innovation Research and Small Business Technology Transfer programs with high-impact emerging technologies such as nanotechnology, information technology, and biotechnology.

NSF's research and education efforts contribute greatly to the Nation's innovation economy and help keep America at the forefront of science and engineering.

Mr. Chairman, I look forward to working with you, and I'd be happy to answer your questions.

[The prepared statement of Dr. Bement follows:]

PREPARED STATEMENT OF DR. ARDEN L. BEMENT, JR., DIRECTOR,
NATIONAL SCIENCE FOUNDATION

Chairman Ensign, Ranking Member Kerry, and members of the Committee, thank you for this opportunity to testify on the importance of basic research. It is a pleasure to appear before you for the first time today.

I am especially pleased that we are able to be talking about competitiveness. As you are well aware, the National Science Foundation is an integral part of the President's American Competitiveness Initiative. The President's request for an 8 percent increase at NSF this year represents the first step in the Administration's firm commitment to doubling the NSF budget over the next 10 years.

The ACI encompasses all of NSF's investments in research and education. These investments—in discovery, learning, and innovation—have a longstanding and proven track record of boosting the Nation's economic vitality and competitive strength.

For over fifty years, NSF has been charged with being a strong steward of the scientific discovery and innovation that has been crucial to increasing America's economic strength, global competitiveness, national security, and overall quality of life.

For many years, the United States economy has depended heavily on investments in research and development—and with good reason. America's sustained economic prosperity is based on technological innovation made possible, in large part, by fundamental science and engineering research. Innovation and technology are the en-

gines of the American economy, and advances in science and engineering provide the fuel.

Investments in science and technology—both public and private—have driven economic growth and improved the quality of life in America for the last 200 years. They have generated new knowledge and new industries, created new jobs, ensured economic and national security, reduced pollution and increased energy efficiency, provided better and safer transportation, improved medical care, and increased living standards for the American people.

Investments in research and development are among the highest-payback investments a nation can make. Over the past 50 years technological innovation has been responsible for as much as half of the Nation's growth in productivity.

Sustaining this innovation requires an understanding of the factors that contribute to it. The Council on Competitiveness, a consortium of industry, university, and labor leaders, has developed quantitative measures of national competitiveness: the number of R&D personnel in the available workforce; total R&D investment; the percentage of R&D funded by private industry; the percentage of R&D performed by the university sector; spending on higher education; the strength of intellectual property protection, openness to international competition; and per capita gross domestic product. A similar set of indicators has been developed by the World Bank Group, and voluminous data have been compiled by NSF. The important point underscored by these indicators is that, for America to remain a prosperous and secure country, it *must* maintain its technological leadership in the world.

Perhaps the Council on Competitiveness' 2004 *National Innovation Initiative* report captured it best by simply stating, "Innovation has always been the way people solved the great challenges facing society."

Often the connection between an area of research, or even a particular scientific discovery, and an innovation may be far from obvious. Fundamental research in physics, mathematics and high-flux magnets supported by NSF led to the development of today's magnetic resonance imaging (MRI) technology. Today, MRIs are used widely to detect cancer and internal tissue damage. Fundamental research on extremophiles, or microorganisms living in extreme environments, led to the polymerase chain reaction, a procedure essential to modern biotechnology, as well as one that allows us to use DNA for forensic evidence. Continuing progress in basic science and engineering research promises more discoveries as well as further improvements in living standards and economic performance.

And still, science and engineering is becoming an ever-larger portion of our Nation's productivity. In the early 1950s, Jacob Bronowski wrote, "The world today is powered by science." I would take this premise one step farther, "No science; no economic growth." Our current level of scientific and technological productivity is what keeps us ahead of our global competitors as the playing field continues to become more level.

NSF has helped advance America's basic science and engineering enterprise for over fifty years. Despite its small size, NSF has an extraordinary impact on scientific and engineering knowledge and capacity. While NSF represents only 4 percent of the total Federal budget for research and development, it accounts for fifty percent of non-life science basic research at academic institutions. In fact, NSF is the *only* Federal agency that supports *all* fields of science and engineering research and the educational programs that sustain them across generations. NSF's programs reach over 2,000 institutions across the Nation, and they involve roughly 200,000 researchers, teachers, and students.

NSF specifically targets its investments in fundamental research at the frontiers of science and engineering. Here, advances push the boundaries of innovation, progress and productivity.

Compared to other commodities, knowledge generated from basic science investments is unique, long lasting and self-leveraging. Knowledge can be shared, stored and distributed easily, and it does not diminish by use. Incremental advances in knowledge are synergistic over time. NSF is proud to have built the foundation for this knowledge-base through decades of peer-reviewed, merit-based research.

Innovation has become the watchword for our Nation's future. It is both a rallying cry and a challenge, one that is now touted by every sector of society—industry, academia, and government.

At the National Science Foundation, we have long heard this clarion call and consider it our most important challenge. Innovation is at the core of what we are about at NSF, and our vision statement reflects that. It is direct and crisp: "enabling the Nation's future through discovery, learning, and innovation."

To realize our mission, we see to it that each of our investments builds intellectual capital, integrates research and education, and promotes partnerships. In all of these endeavors, we focus on the frontiers of knowledge and beyond—the fertile

territory where new ideas are born, nurtured and eventually bear fruit in economic and social returns.

America has always measured its own progress not by comparison with others, but with an eye on the next unmet challenge, the territory unexplored by other nations. That is becoming increasingly difficult with the prospect of nations like China and India building powerful economic momentum through a burgeoning science and engineering workforce and strong research capacity. There is fierce competition for ideas and talent, for comparative advantage and market opportunities worldwide.

As we consider our options for policies that promote and foster innovation—whether it is funding for science and engineering research and education, or incentives for increasing venture capital, or reforms in math and science education—we need to recognize that policies should leave ample room for experimentation and exploration. That is a hallmark of innovation, and a key to our future.

Early last year, the American Electronics Association (AeA) published a report¹ that included the chart below. It illustrates how some of today's ubiquitous technologies have been generated by federally-funded frontier research, and the tremendous role that the Foundation has played in helping U.S. competitiveness and innovation.

Innovation Resulting From U.S. Federally-Funded Research

Innovation	Funder
The Internet	DARPA/NSF
Web Browser	NSF
Bar Codes	NSF
Fiber Optics	NSF
Routers	NSF
MRI	NIH/NSF
Doppler Radar	NSF
Speech Recognition	NSF/DARPA
Nanotechnology	NSF
Computer-Aided Design	NSF/DARPA
Global Positioning Satellites	DARPA
The Mouse	DARPA

Note:

NSF = National Science Foundation.

DARPA = Defense Advanced Research Projects Agency.

NIH = National Institutes of Health.

There was a time, in the 1960s and early 1970s, when the norm was 20 years for the results of fundamental research to find their way to the marketplace. The AeA report describes how Federal funding of solid-state physics, and ceramics and glass engineering in the late 1960s created the knowledge-base for widespread development and use of fiber optic cable in the 1990s. It is also well known that much of this seminal work was performed by private industry as well.

As you know Mr. Chairman, the time frame in which these innovations developed has now collapsed in many fields, often to 20 months or less. The pace of scientific discovery and technological change has accelerated dramatically with the advent of more powerful and sophisticated tools, more robust computing and networking, and the relentless pressure of global competition. Creative disruption at the frontier and reduced lead-time between discovery and application are the principal drivers of global competition today.

In many fields, what was once viewed as a linear process from basic research, to application, to commercialization is now much more multidimensional, complex and parallel. Even the inquiries encountered in developing commercial products and services can generate ideas for frontier research. This give and take blurs the lines between the old categories, and makes innovation a much broader team sport.

What remains vital and constant, however, is a focus on frontier research and education. Transformational research and technological innovation converge on the frontier to produce truly revolutionary progress. Tinkering on the sidelines may be important, but it is not what drives cutting-edge innovation.

It is important to note that in our efforts to advance the frontier, we also aim to enhance development of the Nation's talent pool by integrating research and education. This may be basic research's most profound, and lasting, impact. By pro-

¹Losing the Competitive Advantage? The Challenge for Science and Technology in the United States; American Electronics Association, February 2005.

viding students with significant research experiences throughout their schooling, the world-class scientists, technologists, engineers, and mathematicians trained in this way can transfer new scientific and engineering concepts from universities directly to the entrepreneurial sector as they enter the workforce. This capability is a strong suit in U.S. competitiveness, and one of NSF's greatest contributions to the Nation's innovation system.

And although we are primarily a basic research agency, we are proud of our couplings with the private-sector and industry that fosters innovation and competitiveness for the Nation. NSF's research centers programs, such as our Engineering Research Centers and Science and Technology Centers, directly invite private-sector partners to engage in and/or sponsor related cutting-edge research that can lead to high-leverage innovations. The Foundation's Partnerships for Innovations program develop entrepreneurial pathways to couple new concepts developed in colleges and universities to early adopters in the form of new start-up companies and innovation consortiums between private and public-sector entities.

Furthermore, NSF couples investments in our Small Business Innovation Research and Small Business Technology Transfer programs with high-impact emerging technologies, such as nanotechnology, information technology, and biotechnology. We also co-fund cutting-edge, peer-reviewed research in next-generation semiconductor technologies in partnership with the Semiconductor Research Corporation.

Mr. Chairman, I've only touched upon the variety and richness of the NSF portfolio. NSF research and education efforts contribute greatly to the Nation's innovation economy and help keep America at the forefront of science and engineering. At the same time, NSF-supported researchers produce leading edge discoveries that serve society and spark the public's curiosity and interest. Extraordinary discoveries coming from dozens of NSF programs and initiatives are enriching the entire science and engineering enterprise, and making education fun, exciting and achievement-oriented.

The President's American Competitiveness Initiative makes clear the larger rationale for investments in science and engineering. This is to put knowledge to work—to improve the quality of life and enhance the security and prosperity of every citizen. NSF is committed to cultivating a science and engineering enterprise that not only unlocks the mysteries of the universe but that addresses the challenges of America and the world.

Mr. Chairman and members of the Committee, I hope that this brief overview conveys to you the extent of NSF's commitment to advancing science and technology in the national interest. I look forward to working with you in months ahead, and would be happy to respond to any questions that you have.

Senator ENSIGN. Thank you, Dr. Bement. Dr. Jeffrey?

**STATEMENT OF DR. WILLIAM JEFFREY, DIRECTOR,
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY,
TECHNOLOGY ADMINISTRATION,
DEPARTMENT OF COMMERCE**

Dr. JEFFREY. Chairman Ensign, thank you for inviting me today to testify about the importance of basic research.

The mission of NIST is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. Enabling innovation and competitiveness has been an important part of our mission since we were founded. That mission is becoming increasingly important as the Nation's capacity for technological innovation is increasingly driven by the ability to measure, control, and manufacture ever more complex and small devices. If you cannot measure something, you can't control it. And, if you can't control it, you can't reliably manufacture it. NIST's unique role is to advance measurements and standards so that the next innovation can be realized and commercialized.

NIST's measurement science is focused at the extremes, being able to measure smaller objects faster, or more accurately. One example of how these extreme measurements enable innovation is

the work of our most recent Nobel laureate, Dr. Jan Hall. Dr. Hall significantly contributed to the development of the laser from a laboratory curiosity to one of the fundamental tools of modern science. His research concentrated on improving the accuracy with which lasers can produce a specific sharp frequency or color of light, and the stability with which it can hold that frequency. The development of the laser as a measurement tool enabled a series of innovations and resulted in the creation of whole new industries. These innovations include fiberoptic communications, vastly improved clocks, which enable accurate navigation, precision spectroscopy for detecting minute quantities of a substance, and measurements of fundamental physical constants.

As you can see by this example, NIST's measurement and standards infrastructure is one of the foundations upon which innovation is built. You can think of this as sort of "infatechnologies," as the roads, bridges, and communication networks of the scientific world. Just like the physical infrastructure, this common good ultimately benefits whole industries.

Another area in which NIST's research impacts competitiveness is with standards. Today, thanks in part to NIST, most consumers take it for granted that weights and measures are accurate and that products fit together. That was not always the case. In 1901, there were as many as eight different standard gallons, and Brooklyn, New York, recognized four different legal definitions of "the foot." Today, American consumers and businesses are confident in the quantity of products being purchased, making transactions reliable and cost-effective.

So, how is it that we know that measurements and standards play such an important role in terms of our economic competitiveness? Well, like everything else we do at NIST, we try to measure it.

Over a 7-year period, NIST conducted 19 economic studies to develop an indicator of NIST's impact on industry. These studies document an average direct return to the economy of \$44 for every one dollar spent by NIST.

Recognizing the importance of NIST's role in innovation and competitiveness, President Bush has included NIST as part of the American Competitiveness Initiative. The President's Initiative will give NIST the resources that we need in order to give U.S. industry and science the measurement and standards tools they need to maintain and enhance our global competitiveness.

As part of the ACI, the 2007 budget request for NIST will target the most strategic and rapidly-developing technologies, increase the capacity and capability of critical national scientific assets, meet the Nation's most immediate measurement needs, and improve NIST facilities.

While you've undoubtedly heard of the breakthroughs occurring in nanotechnology, I'd like to close today by describing a similar, but, in some respects, an even more exotic discipline. Quantum physics describes the rules by which electrons, nuclei, and other subatomic particles interact. At these small scales, the laws of our everyday experience break down and new phenomena arise. With several world-renowned scientists, including three Nobel Laureates, NIST is well positioned to develop the tools for measuring and

controlling these quantum phenomena and harnessing their properties to achieve benefits for the Nation.

With my testimony today, I've demonstrated how and why NIST's basic research plays a unique role in our Nation's R&D enterprise. NIST's development of extreme measurement science and standards is the nexus between academia and industry, strengthening our Nation's capacity to innovate, and, thus, compete in the global economy.

Mr. Chairman, thank you for inviting me to testify, and I'd be happy to answer any questions.

[The prepared statement of Dr. Jeffrey follows:]

PREPARED STATEMENT OF DR. WILLIAM JEFFREY, DIRECTOR, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, TECHNOLOGY ADMINISTRATION, DEPARTMENT OF COMMERCE

Chairman Ensign and members of the Subcommittee, I want to thank you for inviting me to testify today about the importance of basic research and the vital role it plays in enabling competitiveness. I have the great honor of being the Director of the National Institute of Standards and Technology (NIST), one of our Nation's oldest Federal laboratories. Our mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards and technology in ways that enhance economic security and improve our quality of life. Enabling innovation and competitiveness has been an important part of our mission since we were founded as the National Bureau of Standards 105 years ago. In the Spring of 1900, when Congress was considering the Act that created the National Bureau of Standards, the accompanying Committee report stated:

" . . . that no more essential aid could be given to manufacturing, commerce, the makers of scientific apparatus, the scientific work of the Government, of schools, colleges, and universities than by the establishment of the institution . . . "

That statement is as true today as it was then. From our early electrical measurement research to today's quantum information science, NIST has long been a center for high-impact basic research.

In today's global economy, the ability of the United States to remain competitive relies increasingly on our ability to develop and commercialize innovative technologies. The amount of scientific components in products has increased dramatically. Just think about how much more complex an iPod is compared to a record player. The ability of America to be technologically-innovative, both drives and is driven by our ability to observe and to measure. If you cannot measure something—you will not be able to control it. And if you can not control it—you will not be able to reliably manufacture it. NIST's unique role, or niche, is to advance measurements and standards so that the next innovation can be realized and commercialized, thus allowing our industries to be competitive. Recognizing the importance of NIST's role in innovation and competitiveness, President Bush has included NIST as part of the American Competitiveness Initiative (ACI). The President's Initiative includes key resources necessary for NIST to develop the measurement and standards tools to enable U.S. industry and science to maintain and enhance our global competitiveness.

When the Secretary of the Treasury proposed the creation of the measurements and standards laboratory that became this agency, he wrote:

"The extension of scientific research into the realm of the extremes of length, mass, time, temperature, pressure and other physical quantities necessitates standards of far greater range than can be obtained at present. The introduction of accurate scientific methods into manufacturing and commercial processes involves the use of a great variety of standards of greater accuracy than formally required."

Extreme measurements are still needed today; the only difference is that today's measurement frontier is smaller, colder, more precise, and more accurate. One example of how these extreme measures impact innovation is the work of our most recent Nobel Laureate, Dr. Jan Hall. Dr. Hall significantly contributed to the development of the laser, first demonstrated in 1961, from a laboratory curiosity to one of the fundamental tools of modern science and a ubiquitous component of modern

communications. His research concentrated on improving the precision and accuracy with which lasers can produce a specific, sharp frequency or color of light, and the stability with which they can hold that frequency. His work has been essential to the development of the laser as a precision measurement tool. This ability to precisely control the frequency and improve stability has enabled a broad range of laser innovations in science and technology, including precision spectroscopy for physical and chemical analysis, new tests and measurements of fundamental physical laws and constants, time and length metrology, and fiberoptic communications, among others.

As you can see by this example, NIST's measurement and standards infrastructure is part of the foundation upon which innovation is built. You can think of this "infrastructure" as the roads, bridges, and communications networks of the scientific world. Just like physical infrastructure, no one person or company can claim enough benefit from the work or has the capability to build this infrastructure. This "common good" infrastructure ultimately benefits whole industries.

Another area in which NIST's research impacts competitiveness is in the area of standards. Standards promote the free market by acting as the "grease" which increases transactional efficiency, resulting in reduced costs and opening of new markets thus enhancing competitiveness. Today, thanks in part to NIST, most consumers take it for granted that weights and measures are accurate and that products fit together. That was not always the case. In 1901, there were as many as eight different standard gallons; Brooklyn, NY, recognized four different legal measures of the foot, and about 50 percent of tested food scales were wrong, usually favoring the grocer. Today, American consumers and businesses can be confident in the quantity of product being purchased—making transactions more reliable and cost-effective.

However, the need for standards has increased as the economies of the world have become linked through global trade. To compete in this global marketplace, U.S. products must meet specified standards for quality and performance. NIST collaborates with other agencies and the private-sector to represent U.S. interests in the development of international standards. Ideally, such standards should not put U.S. products at a competitive disadvantage.

The United States Standards Strategy calls for standards to be developed in an open and consensus-driven process and the resulting standard to be performance-based and relevant, in other words, to create a level playing field for all participants.

This philosophy is not consistently applied in all countries—requiring constant vigilance to prevent standards being adopted by other countries that *de facto* serve as barriers to trade.

NIST works proactively to encourage other countries to adopt standards that satisfy the criterion outlined above. For example, NIST staff has worked with U.S. based organizations, such as the International Code Council (ICC) and the National Fire Protection Association (NFPA) to promote the adoption and use of building and construction standards in different parts of the world—thus opening these markets to exports of U.S. products and services. As just one result, Saudi Arabia has adopted significant parts of the ICC Building and Construction Codes, requiring technologies that are widely used in the United States. The current value of Saudi Arabian new and planned construction is approximately \$35 billion. The Saudi Arabia Standards Organization (SASO) is currently translating the code into Arabic, paving the way for its use in other countries in the region.

So how is it that we know that measurements and standards play such an important role in terms of our economic competitiveness? Well, like everything else at NIST, we try to measure it. Over a 7-year period, 1996–2002, NIST conducted 19 retrospective economic impact studies on a wide range of technologies and industries that can be collectively viewed as a legitimate indicator of NIST industry impact. The average benefit-cost ratio of the studies was 44 to 1. That means for every dollar invested in these projects, we documented \$44 of direct economic benefit to the Nation.

One of the studies looked at the economic impacts of NIST's cholesterol standards program. In 1969, the variability of cholesterol in blood measurements was reported to be approximately 18 percent. Over the following 25 years, NIST—working with the Centers for Disease Control—established and maintained a reference infrastructure for cholesterol measurements that has contributed to a steady decrease in measurement variability to less than 5 percent, representing potential savings of over \$100 million per year in treatment costs for misdiagnosed patients. Additionally, due to the availability of highly-accurate cholesterol reference materials, manufacturers of cholesterol measurement systems experience lower production costs than they would if standard reference materials were not available. They also faced

significantly lower transaction costs than they would if the accuracy of their products was not ‘anchored’ to these nationally-recognized standards.

Maintaining and extending our Nation’s competitiveness is critical to our Nation’s future economic security. To address this, the President has proposed the American Competitiveness Initiative (ACI). One component of the President’s Initiative is the strong commitment to double over 10 years investment in the key Federal agencies that support basic research programs in the physical sciences—the National Science Foundation, the Department of Energy’s Office of Science, and NIST. ACI allocates \$535 million for the high-impact research and facility upgrades at NIST. This is an increase of \$104.1 million over FY 2006—after removing directed grants—a 24 percent increase for our measurement and standards programs. The major focus of NIST’s portion of the American Competitiveness Initiative includes the following:

Targeting the most strategic and rapidly developing technologies (\$45 million):

- Enabling nanotechnology from Discovery to manufacture (\$20 million)—This initiative will fund a national research facility for developing and disseminating nanoscale technologies, and an R&D effort, utilizing the resources of both the facility and NIST’s multidisciplinary labs to develop measurement science, standards, and technology for nanomanufacturing.
- Enabling the Hydrogen Economy (\$10 million)—This initiative will expand research efforts at NIST to develop the technical infrastructure to enable safe production, storage, distribution, and delivery, as well as equitable sale, of hydrogen in the marketplace.
- Quantum Information Science: Infrastructure for 21st Century Innovation (\$9 million)—NIST proposes to accelerate advances in this critical field through three complementary efforts: (1) an expanded in-house program; (2) an enhanced effort to exploit the fundamental properties of quantum systems to develop new metrology tools and methods; and (3) funding for a Joint Quantum Institute.
- Innovations in Measurement Science (\$4 million), and—This initiative will expand the scope and nature of projects selected for the Innovations in Measurement Science Program to allow this program to keep better pace with the evolving needs of industry and science.
- Cyber Security: Innovative Technologies for National Security (\$2 million)—NIST proposes to work with industry and academia to develop measurement science and technologies to identify the level of vulnerability of IT systems, assess the effectiveness of cyber security controls, test system functionality, address vulnerabilities, identify vulnerabilities in real-time, and mitigate attacks.

Increasing the capacity and capability of critical national assets (\$27 million):

- NIST Center for Neutron Research (NCNR) Expansion and Reliability Improvements: A National Need (\$22 million)—This initiative begins a planned five-year program to expand significantly the capacity and capabilities of the NCNR to help meet this pressing national need.
- Synchrotron Measurement Science and Technology: Enabling Next-Generation Materials Innovation (\$5 million)—NIST proposes to accelerate innovation in U.S. materials science by creating a diverse set of scientific instruments at the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory.

Meeting the Nation’s most immediate needs (\$12 million):

- Manufacturing Innovation through Supply Chain Integration (\$2 million)—This initiative will enable an extensive and wide-ranging program with U.S. manufacturers, to develop standards for seamless data transactions throughout global supply chains.
- Structural Safety in Hurricanes, Fires, and Earthquakes (\$2 million)—This initiative will allow the development of technical tools required to enable innovations in multi-hazard risk assessment and mitigation technologies, and the scientific basis to improve the codes and standards used in the design, construction, and retrofit of buildings and physical infrastructure.
- International Standards and Innovation: Opening Markets for American Workers and Exporters (\$2 million)—Under this proposed initiative, NIST will promote U.S. competitiveness by ensuring that innovative U.S. businesses are better equipped to satisfy standards-related requirements in key export markets and that these firms have access to level playing fields.

- **Bioimaging: A 21st Century Toolbox for Medical Technology** (\$4 million)—NIST will partner its expertise in the physical and information sciences with the experience and know-how of the National Institutes of Health (NIH) and the bioimaging industry to develop the needed measurement capabilities to move from simple observation to quantitative diagnosis.
- **Biometrics: Identifying Friend or Foe** (\$2 million)—NIST will develop: (1) tests to determine the accuracy of multimodal systems; (2) image quality standards and standard measurement techniques to improve the accuracy and interoperability of facial recognition systems used for border security; (3) tests to determine the image quality of live-scan fingerprint equipment; and (4) tests and guidelines to assure that future biometric systems are interoperable and work in realistic environments.

Improving NIST Facilities (\$20.1 million):

- Physical improvement to research buildings in Boulder, CO (\$10.1 million).
- Increasing the base for Safety, Capacity, Maintenance and Major Repairs of NIST's Facilities (\$10 million).

In today's modern world, measurements and standards are critically important for such things as the integration of the manufacturing supply chain, development of novel nanomaterials, adoption of a hydrogen economy, and harnessing the power of quantum mechanics. I would now like to take the opportunity to talk about a few of our initiatives and how they will impact the United States' ability to innovate and remain competitive.

America's large manufacturers are globally-distributed enterprises that rely on a system of small manufacturers, parts suppliers, shippers, and raw materials producers organized in extended supply chains. Using the auto industry as an example, the average car has over 15,000 parts coming from 5,000 manufacturers that must be there on time, every time, with the precise specifications of the large manufacturers. Production costs are no longer the only cost drivers in these global supply chains—an increasingly important factor is the cost of engineering and business activities, which depend critically upon clear and error-free exchange of information. Successfully managing production throughout the supply chain is critical to the competitiveness of these extended enterprises. An independent economic study commissioned by NIST found that the U.S. automotive supply chain loses \$1 billion annually from these inefficiencies. NIST research on interoperability standards is the key to successfully "lubricating" these supply chain transactions.

The nanotechnology-related market is predicted to exceed \$1 trillion globally by 2015. Within the next 10 years, experts expect at least half of the newly designed advanced materials and related manufacturing processes to be at the nanoscale. The United States is making significant investments in nanoscience and nanotechnology, and it is essential that we rapidly and efficiently transfer our basic scientific discoveries to practice within our manufacturing sector. Globally, no one country or region has a significant technological lead in this area—with the European Union, Japan, and other countries each investing about the same amount of government resources as the United States. Successfully translating nanoscale discoveries into manufactured products will be critically dependent on: (1) developing process technologies to efficiently and reliably produce commercially-significant quantities of nanomaterials, (2) developing advanced measurement and process-control technologies—including standard reference materials—to monitor production processes and for quality control, and (3) close cooperation and interaction between the research sector, the manufacturing sector, and the national measurement standards system. In order to meet each of these requirements and thus allow the U.S. to be globally competitive, NIST will have to conduct the research to support the development of a measurement and standards infrastructure for nano-products.

Everyone understands that one of the factors affecting our global competitiveness is our dependence on foreign oil. President Bush issued a challenge to the Nation's scientists and engineers in his 2003 State of the Union speech to overcome technical obstacles so that "the first car driven by a child born today could be powered by hydrogen, and pollution-free." In order to make this vision of a hydrogen economy a reality, measurements and standards must lead the way.

For the past 50 years, NIST has been a leading provider of data on the chemical and physical properties of hydrogen. NIST's Center for Neutron Research (NCNR) is a premier facility for the study of hydrogen. The NCNR was cited by a 2002 working group of the White House Office of Science and Technology Policy as "the highest performing and most used neutron facility in the United States." The NCNR already is being used in conjunction with major U.S. manufacturers to study the flow of hydrogen through operating fuel cells to help improve the efficiency and dura-

bility of these devices. NIST is, in fact, the lead agency for weights and measures for vehicle fuels and will need to develop physical reference standards, calibration services, and new consensus standards to help ensure equitable trade of hydrogen in the marketplace. Moreover, NIST's expertise will be critical for advancing hydrogen process control technologies, the design of fuel cells, and the development of innovative tools needed to make the hydrogen economy a reality.

America's future prosperity and economic security may rely in part on the exotic properties of some of the smallest particles in nature to accomplish feats in physics, information science, and mathematics that are impossible with today's technology. Quantum information science seeks to use the fundamental properties of nature at very small scales to build technologies that can only be imagined today. While classical physics describes the way objects interact at the everyday scale, quantum physics describes the rules by which electrons, nuclei, and other subatomic particles interact. At these small scales the laws of our everyday experience breakdown and new phenomena arise. This revolutionary new technology offers potential solutions to issues looming on the horizon of technology development, including the limits of Moore's Law on the microelectronics industry. Around the year 2015, the microelectronics industry will reach its limit in reducing the size, and increasing the processing speed, of integrated circuits manufactured by traditional silicon technology. Additional process power and capacity will then only be achieved through revolutionary technologies such as quantum information. With several world-renowned scientists, including three Nobel laureates, NIST is perfectly positioned to play a more critical role in developing the tools for measuring, controlling, and ultimately understanding the quantum realm and harnessing its power to achieve benefits for the Nation.

With my testimony today, I have demonstrated how and why NIST's basic research plays a unique role in our Nation's research and development enterprise. NIST sits at the nexus of science and industry, conducting extreme measurement science and developing standards that allow industry to innovate and compete in the global economy. The President's 2007 budget recognizes this role and provides our researchers the ability to keep advancing the critical measurements that will enable U.S. industry to develop the most advanced and best products and services. Mr. Chairman, thank you for inviting me to testify today. I would be happy to answer any questions.

Senator ENSIGN. Thanks to all of you.

I want to ask a question and have each of you comment. And it is fine if we go back and forth. I want to discuss how you decide what is a meritorious grant proposal. Obviously, we have peer review to try to rate the various grant proposals. From what I understand, there is an entire rating system that goes along with this process. One of the things that I want to explore before we go into the amount of money that may be required to meet the needs of the grant proposals, rated excellent or very good, is how we are and how we should be assessing the merits of each grant proposal.

We were with the President yesterday. He convened several Senators, a bipartisan group of us, along with the Secretary of Education, to talk about the various proposals, the National Innovation Act, which Senator Lieberman and I introduced, the PACE proposal, and the President's American Competitiveness Initiative. It was a very good meeting. And we talked about various topics. But Chairman Mike Enzi, from the HELP Committee, mentioned what they do with peer review over in Ireland. I guess they have a second panel of the peer review, involving business. So that you have academics on the first peer-review panel, and you have representatives from business conduct a second peer review, because there are limited funds. And so, I would like to hear any of your comments on a peer review system like that being set up in the United States.

Dr. MARBURGER. Let me start answering that question, and I'll pass it on to my colleagues.

The National Science Foundation has the distinction of having a particularly well-regarded peer-review process for its grant programs. And I might add that the Irish system is modeled on our system very closely. But this is a new feature, that you mentioned.

I believe that some types of grants do require input from the nonscience community, a community of people who attempt to translate technology into commercial products. And most agencies that have applied missions work very closely with industry in order to calibrate themselves and their judgment. I know NIST, among agencies, probably works more closely with industry, and has a very effective relationship in that regard.

But I'd like to ask my colleagues to respond to that, as well. I think it is appropriate, in certain contexts, to have that kind of input.

Dr. BEMENT. Well, I would respond a couple of ways. First of all, there has been a program in existence for some time that has had that two-level review. It was the Advanced Technology Program. The first review dealt with scientific or engineering or technical merit. The second review really had to do with business feasibility, or had to have a good business plan.

At the National Science Foundation, we feel that our mission is to work at the frontier, because if we vacate the frontier, we do a disservice to the Nation, so that we're looking for investigators who see the frontier, or maybe even see beyond the frontier, and determine, or at least have some concepts of, where the next big move of the frontier will come.

That's generally called high-risk research or transformational research or frontier research. There are a lot of designators. On the other hand, at the other extreme we also have programs, like the SBIR and the STTR program, that do deal with the private-sector—they're usually small businesses—where we also look at the technical feasibility and the business feasibility of the concept. But in even those cases we try to be sure that we pick those projects that are at the cutting-edge of emerging technologies, whether it's nanotech or information technology or biotechnology, to be sure it's moving new technologies forward, rather than just embellishing existing technologies.

Senator ENSIGN. Good.

Dr. JEFFREY. I'd just like to expand upon some of the comments that Dr. Marburger made. NIST does work very closely with industry. In fact, one of the features is that we have as many technical researchers on our campus that come from industry and universities as we actually have NIST researchers. So, we have about 1,800 guest researchers a year.

In addition, we work with industry consortia in developing technical roadmaps that help guide what the investment strategy would be. One of the more long-term relationships we've had is with the semiconductor industry. In addition, we work with other industry consortia in all disciplines, again, trying to identify the highest-priority needs, because we do, as Dr. Marburger said, "fill that niche between the pure fundamental transformational research," that Dr. Bement was talking about, and then what industry's requirements are for the future.

Senator ENSIGN. I just raise the point, because when Senator Enzi mentioned that yesterday, Dr. Bement, what you said struck me. That is why I wanted to hear your comments on it. I think there is a place for that, but you also have to have that transformational foundation research. I think it is really important. Because we do not know whether a lot of the research is ultimately going to be applicable to anything. Someone may have an exciting idea to pursue something, but the researchers, scientists, and policy makers do not know whether a lot of these are going to be dead-ends. You have to pursue some dead-ends.

I always think back to Thomas Edison and to the number of experiments that he did that went nowhere before he conducted experiments that were very, very successful. I think that is the type of thinking that NSF is especially involved with and why I think it is important to bring it out. And to have that discussion in public could be helpful going forward.

Now I want to address now the fact that I proposed and the President proposed, significantly increasing funding for NSF and NIST and in a more targeted approach than some others have done. Senator Lieberman and I took a slightly different approach with the National Innovation Act, but, still, I think our approach is very similar philosophically with the President's proposal. My legislation seeks to use a lot of the dollars that we have effectively, and increase funding where we can and must. And, just to make that comment, and to re-emphasize this, I am as fiscally conservative as anybody in the U.S. Senate. There are two areas that I think give us a great return for our whole economy, where all Americans benefit, where the investment is not a drain, actually, on the Federal budget. Rather, you actually, you get a positive return. Basic research is absolutely one of those areas. And infrastructure is the other area. And some of these infrastructure investments end up being in cyberinfrastructure in some of the things that we have seen.

But with all of the proposals that we have out there that are rated—and I guess I want to get the comments that—OK, we've proposed, for instance, in our legislation, doubling NSF. And we targeted some increased support for NIST. Can you comment—and, once again, I'll have the whole panel comment—on if what we've proposed is adequate? Would it meet a lot more of the needs? How much more would you need—if you had to put a dollar figure on it—to meet what you would consider all of the meritorious grants that are out there.

Dr. BEMENT. Do you want me to comment?

Dr. MARBURGER. The President's budget request for the American Competitiveness Initiative tries to make priorities, and tries to identify the things that really need to be boosted right now in order for us to maintain this very long-term capability of producing new science that will lead to new technologies in the long-term. And there are—because of the generous funding that this and some previous Administrations have given to basic science, many parts of our scientific enterprise are funded in a way that's nearly commensurate with their challenges and opportunities. But there were a few areas, particularly in some aspects of the physical sciences, and departments like NIST, for example, that create tools for ev-

everybody else, that we felt were really underfunded, relative to their challenges. And the President's budget request recognizes those challenged areas. And that's why there is not only a pretty significant boost in the first year, but also a commitment to those departments, over a long period of time, to try to focus on them and build them up to—so that they can be where they need to be. We're not trying to do this all at once, but over a period of time.

So, you can imagine, my answer to your question, Mr. Chairman, is that we put the proposal together, aware of what the needs are and what the capacity is, and this is what we think is the appropriate amount.

Senator ENSIGN. OK.

Dr. Bement?

Dr. BEMENT. I would have both a philosophical and a pragmatic answer to your question. The question, "How much investment in research and development is enough?" has plagued industry, the private-sector, the public-sector for many, many years. My feeling about it is, it's enough if it builds the capacity that the Nation needs, in terms of a STEM workforce that can take on the new jobs to develop the new technologies that are coming along. It will be enough if it broadens participation so that women and under-represented minorities can be part of that workforce. It will be enough if we provide the very best math and science education to our children, from pre-kindergarten all the way up through graduate study. And it will be enough if it keeps the United States in a leadership position in the key technical fields around the world, so that we can be competitive. If not the leaders, at least equal, or at least with enough capacity that we can be fast followers if new concepts emerge elsewhere in the world.

Now, to put a number on that would be far beyond anything that we could possibly handle in our current discretionary budget. On the other hand, I have to say that the ACI is a first big step in moving in that direction.

Senator ENSIGN. Thank you.

Dr. JEFFREY. Just to elaborate on that, NIST is that little yellow sliver at the top on the chart. It's one of the pieces, again, as part of the technical infrastructure for the Nation, that has played a really important role, and as, again, the economy is becoming more technical, will play an increasingly important role.

The plan for ACI is exactly what we need, at the right time. It not only increases our ability to do some of the research, but it also increases our capability and capacity, in terms of some of our infrastructure. And so, it was well thought through, and, again, would be exactly what we need at this point.

Senator ENSIGN. Great. One last question that I have for this panel is that, in doing some reading about what Michael Milken has done with prostate cancer in the Foundation, and experiencing some of what National Cancer Institute and NIH have done in the life sciences—and I know that some of the things are done differently with the physical sciences—but, I'm just finishing one of the books that was written about what they had done. One of the things that they discovered was that the grant proposals that people had to submit were very cumbersome, long and inflexible. It would take grant applicants a long time to write the grant pro-

posals. But now, they limit grant proposals to five pages. The grant proposals would have to be five pages. As I recall, the other thing that they did was give increased flexibility. I guess what happened a lot of times in the life sciences is that the way the grant proposals and the strict criteria was written, sometimes halfway through a research project, a researcher would realize a project was not going anywhere, but the researcher was not allowed to adapt, because of the strict criteria written to this grant proposal. You could only spend the grant money for this particular project in this particular way. There was not enough flexibility. So, they tried it in the private-sector, they felt like they had more ability to give the researchers that added flexibility.

Any comments on that type of an approach? Is it possible—is government able to do this?

Dr. BEMENT. Yes.

Senator ENSIGN. Is government able to be that flexible? And is it possible to streamline—are you always looking at ways to streamline the grant proposals, but still get enough information on whether grant proposals are meritorious?

Dr. BEMENT. On the National Science and Technology Council, there is a Business Practice Subcommittee that's looking at how to normalize these processes across all the Federal agencies. In our experience at the Foundation, since many fields of research are becoming more complex, proposals may involve more than one principal investigator and in some cases, are highly interdisciplinary. Our experience is that about 20 pages are about optimal to fully describe the research. On the other hand, we do have a Small Grant for Exploratory Research program, which tries to pay attention to areas that are really beyond the frontier. These are really new concepts. And for those types of proposals, we accept much shorter proposals, about three or four pages. And the program officer has a fair amount of discretion in approving those kind of proposals.

Senator ENSIGN. OK.

Dr. MARBURGER. Dr. Bement referred to the National Science and Technology Council. OSTP staffs the interagency working groups for this council. And, by popular demand several years ago, this committee that Dr. Bement referred to, on business practices and business models, was created to identify best practices among all the agencies. The grant approval and evaluation process does differ from agency to agency. And some agencies have more cumbersome processes than others.

National Science Foundation has good practices in this area, with a variety of evaluation mechanisms. And this interagency group is trying to encourage other agencies to follow this model and to be even more flexible. We recognize that there is a burden on investigators for all this paperwork and writing reports and so forth.

But NSF has been very good at being able to get money to people to follow up things like damage to the levees in the Katrina Hurricane last year, in following up the damage—deplorable damage to the World Trade Center after 9/11. NSF was able to get money to investigators to go in immediately after the collapse of those buildings and perform preliminary investigations, seemed to me, almost

within hours, if not days. So, with a capacity like that, we clearly have the mechanisms to respond quickly to opportunities and situations where immediate scientific analysis would be helpful in the long-term, and we just have to spread those best practices. That's one of the reasons that the National Science Foundation was selected for inclusion in this priority ACI, because they do have an excellent track record for getting the money out.

Senator ENSIGN. I agree with that.

Dr. JEFFREY. I have nothing to add to that.

Senator ENSIGN. OK.

Senator Pryor?

**STATEMENT OF HON. MARK PRYOR,
U.S. SENATOR FROM ARKANSAS**

Senator PRYOR. Thank you, Mr. Chairman. I'm sorry I was late.

But let me, if I can, Dr. Jeffrey, ask you about the Advanced Technology Program. Have you covered that yet, Mr. Chairman, the Advanced Technology Program? That much? OK. Well, we—

OK, well, the program is one of the only programs directed at innovation that has been actually called effective by the National Academy of Sciences. Dr. Jeffrey, do you agree that it has been effective?

Dr. JEFFREY. I believe that the OMB PART score for ATP was "adequate." So, within its area, that it has made some very substantial progress.

Senator PRYOR. OK. And as I understand it, in the President's budget, that line item's been zeroed out. If we are able to restore that funding, would you be opposed to us restoring that funding?

Dr. JEFFREY. Well, the way that the budget was put together is, trying to look at the priorities, based upon a number of things, including, reduction of the deficit. And in those priorities, I talked about in my opening statement, was the role that NIST plays in terms of the general technical infrastructure and the things that we do that support entire industries. The ATP has been effective, as you said, in terms of support of specific technologies in specific companies. But in terms of the priorities, we're looking at the broader base impacting the entire economy and entire industries. And so, the priorities would certainly be with the basic lab programs.

Senator PRYOR. OK. Dr. Bement, let me ask you—there's an increase in funding for NSF research and development, and I'm just curious about the additional money. How are you going to spend that this year? What's the expectation there?

Dr. BEMENT. Yes. Our first priority is to advance the frontier. So, that's focused on building up our core research capabilities among our different directorates. The second priority is broadening participation. And significant increases have gone to those programs that have had a very significant impact on getting larger numbers of under-represented minorities, persons with disabilities, into the STEM fields, at all levels, including Ph.D. programs. The third priority is to invest in the infrastructure in the major facilities that are truly transformational, with significant investments in cyberinfrastructure, which is having a revolutionary effect on how research is being conducted and the levels of complexity that we

can now deal with in understanding science. And the final priority, not necessarily least, is to put more resources into our math and science education program.

Senator PRYOR. All right. Let me follow up on that, if I can. Just generally, who makes those decisions about how to spend money? You've listed out your priorities, but who, in the final analysis, actually makes the decision on where the money goes?

Dr. BEMENT. We go through a fairly elaborate budget preparation process, listening to the community, first of all, getting inputs from our Advisory Committees and through workshops, and also by listening to Congress. We understand there are priorities, from previous years' appropriations. Then we assemble that information, try to synthesize it, and then we review it with the National Science Board. And the National Science Board ultimately approves our budget. And that review takes place in several sessions throughout the spring and summer, prior to our submitting our budget to the OMB in September.

Senator PRYOR. OK. And you mentioned math and science, as well. Is that part of the President's American Competitiveness Initiative?

Dr. BEMENT. It is. It's part of building the workforce for the 21st century.

Senator PRYOR. And how—in your view, is that going? I mean, do we have a good game plan to make progress there? Because I know there have been some cuts in the education budget, et cetera. But, from your perspective, how's that looking?

Dr. BEMENT. I think it's going exceptionally well. In our Math and Science Partnership program, we have currently done an assessment of our first year cohort after 1 year of results in testing. We've been able to show that, in the elementary grades, we've been able to improve proficiency by at least 4 percentage points, and, in the high schools, we've been able to increase it by as much as 14 percentage points. Now, that's quite significant. But that's only 1 year of results in the partnership. We expect that those will continue to go up.

And in some specific schools, the results are really quite impressive. I learned, this morning, a report of a school, in Pennsylvania, who now ranks first in the world, by international testing, in math and science performance at the fourth grade. They tied with Korea. They were tied for first place. And in the tenth grade, in the same school, they came in second in the world, second only to Sweden. These are quite dramatic results.

And they are a member of our Math—they are a——

Senator PRYOR. OK.

Dr. BEMENT.—participant in our Math and Science Partnership program.

Senator PRYOR. Well, maybe I misunderstand, but has the NSF eliminated new Math and Science Partnership grants——

Dr. BEMENT. No, that's not——

Senator PRYOR.—and transferred—transferred those over to Department of Education.

Dr. BEMENT. No, that's not correct, Senator. The program is forward funded. Each of the 48 projects under the Partnership have a 5-year grant. There is adequate funding in the program, at the

present time, to continue those grants. We expect that they will be continued until they're completed. In addition to that, there's—

Senator PRYOR. But are there new grants coming on?

Dr. BEMENT. No. We currently have 48 Partnerships, and the—those are not being increased. But this, basically, is a research and development program that involves 5,000 schools, 500 school districts. It's the largest research and development program of its type that has ever been mounted. And so, our next challenge is to deal with scaling that up through implementation by working with the Department of Education and with the State departments of education.

Senator PRYOR. OK.

Mr. Chairman, I think that's all I have. Thank you.

Senator ENSIGN. Well, thank you.

I want to thank the witnesses for your excellent testimony. And we really look forward to working with you. This is a critical area of our economy. We all know that. And so, the exciting part about it is that there is a lot of bipartisan support for what we're trying to do going forward. And, as we know, these days, anything that can be bipartisan, we are looking for. So, we are excited about going forward with some of these proposals.

So, thank you. I would now like to call the next panel of witnesses to the table.

Our second panel has four witnesses. The first witness on the panel will be Dr. Steven Knapp. Dr. Knapp is the Provost and Senior Vice President for Academic Affairs at Johns Hopkins University. The next witness will be Dr. Leonard Pietrafesa. Dr. Pietrafesa is the Chairman of the National Oceanic and Atmospheric Administration's Independent Science Advisory Board. The next witness will be Mr. Philip Ritter. Mr. Ritter is a Senior Vice President and Manager of Public Affairs for Texas Instruments. And our final witness today will be Dr. Adam Drobot. Dr. Drobot is the Chief Technology Officer for Telcordia, Incorporated.

We'll start with Dr. Knapp.

STATEMENT OF STEVEN KNAPP, Ph.D., PROVOST AND SENIOR VICE PRESIDENT FOR ACADEMIC AFFAIRS, JOHNS HOPKINS UNIVERSITY

Senator ENSIGN. Dr. Knapp, could you push your microphone, please to make sure it is on? There you go.

Dr. KNAPP. Is that better? Thank you.

As you can see from the item displayed to my right here, Drs. Brody and Barrett were recently joined by over 140 business, academic, and other national leaders in support of the innovation agenda. I'm pleased to have the opportunity today to share our University's perspective on this important issue.

The United States has long been the world leader in scientific discovery, thanks in large measure to policies that encourage innovation, improve education at all levels, and facilitate the transfer of knowledge from the lab to the marketplace. But today we face serious threats to this preeminence. Other nations bring to the table strong education systems, focused government policy, and low-cost workers. Asia and Europe are committing unprecedented resources to science and engineering.

Basic research is essential to our capacity to meet this challenge. Our ability to compete in the global economy depends, first and foremost, on our ability to make new discoveries. The more we learn about how things work, the principles of basic biology, chemistry, physics, and mathematics, the more opportunities we have to put that knowledge to use building businesses, creating products, improving our standard of living, and preserving the security of our Nation.

Today's most innovative industries are built on decades of basic research, research that had no discernible practical application when it was undertaken. And, Mr. Chairman, you mentioned some examples of this in your opening comments. And, just to highlight a few of those:

Quantum mechanics spawned the semiconductor industry and the information revolution. CDs and DVDs? We would still be using vinyl and videotape if not for lasers, which are based on ideas that have their roots in the theoretical work of Albert Einstein.

In the United States, funding basic research has long been a government function. Why is that the case? Because basic research must be sustained for years or decades, sometimes coming to nothing, and entails no immediate return on investment. There is no entity other than government that can take on this role.

But U.S. Federal research and development spending, as a percentage of gross domestic product, peaked 40 years ago, in 1965. It was then just below 2 percent of GDP. In the past 40 years, that share has diminished by more than half, to about .8 percent of GDP.

We must reverse this trend now by strengthening the Nation's commitment to science-related Federal agencies and programs, particularly NSF and NIH, the Department of Energy's Office of Science, NASA, and the basic research programs sponsored by the Department of Defense.

In Fiscal Year 2005, Johns Hopkins won \$1.28 billion in Federal R&D funding, won that competitively. That support allowed us to improve medical care worldwide, advance human knowledge, and train new generations of innovative researchers.

But investment in research universities yields tangible economic benefits, as well. In 2004, Johns Hopkins produced 89 patents. That same year, our friends at the University of California won 270 patents, MIT won 159, and Caltech, 142. In all, there were more than 3,200 patents issued that year to U.S. universities. That's a tremendous amount of knowledge made available to American business and the American public.

Johns Hopkins strongly supports efforts to secure the competitive strength and national security of the United States by bolstering the Nation's ability to innovate. The National Innovation Initiative, the National Academy's report, *"Rising Above the Gathering Storm,"* President Bush's American Competitiveness Initiative, the National Innovation Act, and the PACE Acts, each of these welcome efforts is bringing the role of basic science and innovation forward for discussion and debate. Each envisions increased support for Federal science agencies.

I'd like to thank Senator Ensign for his leadership on these issues and for introducing, with Senator Lieberman and others, the National Innovation Act.

As we engage in this discussion, it is crucial to stress that the physical sciences should not be funded to the exclusion of the life sciences. Today biologists, statisticians, physicists, engineers, and computer scientists all work together to advance the knowledge we need to solve our urgent problems.

And to just mention an example that was not in my written testimony, we have an exciting case of a young biomedical engineer, named Dr. Jennifer Elisseeff, who has figured out how to grow replacement cartilage tissue for knee replacements. And she does this by inserting cartilage cells into a chemical medium that is a "smart" gel medium that actually chemically signals the cells how much they should grow, and, when the cells reach a certain stage of maturity, they signal this chemical medium to disappear, to dissolve. And she has now patented that, and a start-up company is working on what could be a critical technology for a very serious health problem affecting many of us in the United States.

Sustained real growth in funding for all kinds of basic research is vital. Last year, with the support of the NIH, Johns Hopkins established the Nation's first Institute for Computation Medicine. It is staffed by biomedical researchers and physical scientists from our schools of medicine and engineering, using powerful computers that will mine data for new and more effective ways to treat disease. It's noteworthy that approximately \$2 billion of NIH funding supports research in the physical sciences.

If NIH funding continues to erode, we are concerned that projects that meld physical and biological sciences, such as the Institute for Computational Medicine, could be among the first to suffer.

In general, we applaud the efforts of our leaders in Washington to strengthen American competitiveness. If we at Johns Hopkins can assist, please contact us. I invite you to visit our campuses, explore our facilities and meet our researchers face-to-face. You will find no more persuasive argument for the inestimable value of investment in research than witnessing the innovative enterprise firsthand.

Thank you.

[The prepared statement of Dr. Knapp follows:]

PREPARED STATEMENT OF STEVEN KNAPP, PH.D., PROVOST AND SENIOR VICE
PRESIDENT FOR ACADEMIC AFFAIRS, JOHNS HOPKINS UNIVERSITY

Mr. Chairman, members of the Committee:

Thank you for inviting me to testify this morning. As you may know, Johns Hopkins has been engaged with the innovation issue for a number of years—primarily through the efforts of our President, Dr. William R. Brody, and most recently through his work on the National Innovation Initiative with Intel Corp.'s Chairman, Dr. Craig Barrett. I am pleased to have the opportunity today to share our University's perspective on this important issue.

The United States has long been the world leader in scientific discovery, thanks largely to government policies that encourage innovation, improve education at all levels, and facilitate the transfer of knowledge from the laboratory to the marketplace. Today we face serious threats to this preeminence. Other nations bring to the table strong educational systems, focused government policies, and low-cost workers. Asian and European countries are committing unprecedented resources to science and engineering programs.

Basic research is essential to our ability to meet this challenge. President Brody puts it this way: “Knowledge drives innovation. Innovation drives productivity. Productivity drives economic growth.” Our ability to compete in the global economy depends, first and foremost, on our ability to continue making new discoveries. The more we learn about how things work—the principles of basic biology, chemistry, physics, and mathematics—the more opportunity we have to put that knowledge to use. When we know more, we can use that knowledge to make our world better, to build new businesses and devise new products, and to improve our standard of living.

America’s most innovative industries are built on decades of basic research, research that had no discernable practical application at the time it was undertaken. No practical application, that is, until a light bulb went on in someone’s head; until someone said, “I can use that to make something.”

For example:

- The highly theoretical world of quantum mechanics spawned the semiconductor industry and the information revolution.
- Johns Hopkins scientists thinking about the principle of physics called the Doppler effect used it to invent what became today’s global positioning system.
- Two Johns Hopkins biologists shared a Nobel Prize in 1978 for using restriction enzymes to cut DNA into fragments. Had that esoteric basic research not been done, we would not today have a thriving biotechnology industry in this country.
- And what about CDs and DVDs? You would still be using vinyl and videotape if it were not for lasers, the roots of which go back to theoretical work by Albert Einstein.

In the United States, funding basic research has long been a governmental function. Why? Because it takes a long time to do it, because there is always a risk that any single project will come to nothing, and because it is difficult to capture an immediate return on investment in an idea that has not yet been developed to the stage of a marketable invention.

Despite a societal consensus that basic research is a government responsibility, however, U.S. Federal research and development spending, as a percentage of gross domestic product, peaked *forty years ago*, in 1965, at just below 2 percent of GDP. In the past 40 years, that percentage has diminished by more than half, to about 0.8 percent of GDP. Overall R&D spending, especially in basic sciences, continues to decline.

We must reverse this trend now, by strengthening the Nation’s commitment to science-related Federal agencies and programs, particularly the National Science Foundation, the National Institutes of Health, the Department of Energy’s Office of Science, the National Aeronautics and Space Administration, and the Department of Defense’s basic research programs.

Research and Innovation at American Universities

The Johns Hopkins University is the Nation’s leading recipient of Federal research grants. In FY 2005, our researchers attracted \$1.28 billion in Federal R&D funding and \$1.44 billion in overall R&D funding, a category in which Johns Hopkins has led all U.S. institutions for 25 consecutive years. This support allows us to improve medical care worldwide, advance human knowledge, and train new generations of innovative researchers.

But investment in research universities like Johns Hopkins yields tangible economic benefits as well. In FY 2004, Johns Hopkins alone produced 89 patents, filed 402 new patent applications, and generated \$6.3 million dollars in income from technology licenses. That same year, our friends at the University of California won 270 patents; MIT won 159 and CalTech, 142. In all, there were more than 3,200 patents issued to U.S. universities. That is a tremendous amount of knowledge made available to American business for commercialization and to the American public for an incalculable range of benefits.

Here are just a few recent examples from my own institution; my counterparts at other major research universities, were they here today, would provide examples equally illustrative of the point:

- Johns Hopkins has filed for a patent for self-assembling cubes, the size of a speck of dust, that can carry medicine into the body. These devices, which come out of an NIH-funded collaboration between engineers and radiologists, open up possibilities for the pharmaceutical industry for a new generation of “smart pills” aimed directly at a diseased or injured part of the body.

- The Johns Hopkins Applied Physics Laboratory has greatly improved molecularly-imprinted polymers, or MIPs. These are special materials that can be tailored to detect specific chemical substances. We are now working with a startup company to develop products using this patented technology to improve drinking water and treat wastewater.
- Thanks to the licensing of our technologies to industry, one company outside Baltimore sells thin films that weld materials together in thousandths of a second. Another is developing products to improve the detection of explosives.
- There is a company using Johns Hopkins technology to analyze bone health. Another is using technology originally created to detect submarines to analyze instead the sound of the beating human heart.

Renewing Our Commitment to Basic Research

Johns Hopkins strongly supports efforts to secure the competitive strength and national security of the United States by bolstering the Nation's ability to innovate. The National Innovation Initiative, the National Academy of Sciences report *Rising Above the Gathering Storm*, President Bush's American Competitiveness Initiative (ACI), the National Innovation Act, and the Protecting America's Competitive Edge (PACE) Acts: each of these welcome efforts has helped to get the issue of basic science and innovation on the table for discussion and debate. Each envisions increased support for Federal science agencies. The ACI, for example, calls for increased funding for programs at the National Science Foundation, the Department of Energy's Office of Science, and the National Institute of Standards and Technology.

As we engage in this discussion, it is crucial to stress that the physical sciences should not be funded to the exclusion of the life sciences. Today, biologists, statisticians, physicists, engineers, and computer scientists all work together to advance the knowledge we need to solve our most important problems.

Unfortunately, we tend at any one time to favor life sciences over physical sciences or vice versa, starving one to feed the other. That must not happen. The nature of scientific innovation today means that starving one starves both.

The basic life sciences research funded by the National Institutes of Health is a key component of our overall national science agenda. This Fiscal Year, spending for the NIH has been cut \$66 million. This was the first cut to the NIH since 1970. For FY07, the President has requested \$28.43 billion—essentially a freeze at the current level. And the number of new NIH grants has already tumbled nearly 15 percent from its peak in 2003, hobbling the ability of scientists to open up new lines of investigation.

Last year, with the support of the NIH, Johns Hopkins established the Nation's first Institute for Computational Medicine, staffed by biomedical researchers and physical scientists from our School of Medicine and School of Engineering. Using powerful information management and computing tools, research teams will mine data, model molecular networks, identify biomarkers of disease at early stages, and find new and more effective ways to treat disease.

As NIH funding erodes, we are concerned that projects that meld physical and biological sciences, such as work of the Institute for Computational Medicine, could be among the first to suffer. These projects provide a vital foundation both for medical advancement and for innovation, the kind of innovation that leads to economic growth. They should be supported.

Visa Policy

Return on our national investment in basic research will be most fully realized only if universities can continue to attract the best and brightest from around the world. Research universities have relied on open visa policies designed to promote international intellectual exchange. But today, delays and difficulties in obtaining visas to the United States have contributed to a declining in-flow of scientific talent. At Johns Hopkins, for instance, the number of graduate students from China declined from 328 in 2001 to 178 in 2004. The number of foreign undergraduate students dropped from 355 in 2001 to 263 in 2004.

Competitor nations, meanwhile, are quite naturally taking advantage of our increasingly cumbersome visa process to lure top talent away from the United States. And with the strengthening of foreign science, there are many attractive substitutes abroad for U.S. degree programs, fellowships, and academic conferences.

No question: it is critical that Federal policy protect our national security. At the same time, however, we must foster an environment favorable to international students and scholars. Immigration policies should make it easy for the best and brightest to come here, to stay here, and then to live and work here when their studies are complete. Johns Hopkins supports government policies and contracting

practices that facilitate rather than hinder participation by international students and scientists in the conduct of unclassified fundamental research.

K-12 Education

Neither strong investment in research nor participation from abroad will preserve America's competitive edge in the long-term if we do not repair our faltering K-12 education system, especially in the areas of mathematics, science, engineering, and technology. Advanced research at universities can only be built on a foundation of basic education.

Since 1980, America's nonacademic science and engineering jobs have grown at more than four times the rate of the U.S. labor force as a whole. But in the same two and a half decades, the performance of K-12 students in science and mathematics has declined. According to figures cited by the Association of American Universities, U.S. fourth graders score well against international competition in math and science testing. By the 12th grade, however, our students have fallen to near the bottom.

This weakness also shows up at the postsecondary level. In 1966, American-born students earned 77 percent of science and engineering Ph.D.s awarded in the United States, while foreign-born students earned 23 percent. In 2000, it was 61 percent for U.S.-born students and 39 percent for those from abroad.

At Johns Hopkins, we are able to attract and enroll well-qualified students, but our elementary and secondary education experts' work with schools around the country reminds us daily that the problem of deficient K-12 education in math and science must be addressed—and soon.

Colleges and universities are stepping in to help. At Johns Hopkins, we provide enrichment for talented students and programs to attract young people into science and technology careers. We help schools reform their curricula. We work to train new teachers, including scientists or engineers looking for a second career.

But government action is obviously needed as well.

The National Innovation Act, the Protecting America's Competitive Edge Acts, and President Bush's American Competitiveness Initiative all address this problem. I would like to thank Senator Ensign for his leadership on these issues, and for introducing, with Senator Lieberman and others, the National Innovation Act (S. 2109). This legislation is an important step toward solving many of the issues before us today. I hope that we will continue to see bipartisan cooperation, both here in the Senate and in the House, on all these proposals.

I would like to offer two examples of what can be accomplished by strong K-12 programs. Ryan Harrison and Abe Davis are two incredibly gifted and successful Baltimore students. Both were enrolled in Baltimore Polytechnic Institute's special foundation-funded "Ingenuity Project" for gifted math and science students. Both worked with some of the city schools' most accomplished teachers; both received dedicated and generous mentoring from Johns Hopkins researchers.

Thanks to their talent and these advantages, Ryan and Abe were able to make extraordinary advances while they were each just 17 years old. Ryan, working in a chemical and biomolecular engineering lab at Johns Hopkins, extended the abilities of a molecular biology program called Rosetta. He wrote code late into the night until he had come up with a way to predict protein behavior at varying pH levels. Abe also invested impossible hours in his project, building an immensely complex computer graphics model of the thousands of bounces and collisions that result from dropping scores of balls into a box.

Someday, Ryan's work may help make it possible to create antibodies customized to fight a particular patient's cancer. Who knows what startling uses medical researchers, scientists, and engineers might find for Abe's computer simulation technology?

Both Ryan and Abe are winners in Intel's Science Talent Search. Ryan is now a student at Johns Hopkins and part of our Baltimore Scholars Program, which provides full scholarships to graduates of Baltimore's public high schools who earn admission to the university.

Unfortunately, these successes are far from the norm. The kinds of advantages Ryan and Abe enjoyed simply are not available in the classrooms of most American students, including many of those with real math and science talent. Students from disadvantaged backgrounds have been especially shortchanged.

From early childhood and preschool education through high school, there are heroic, but isolated, efforts under way around the country to better prepare the children of America to make the discoveries and technological advances that will save lives, improve living, and drive the economy forward. Those isolated efforts, however, must become systemic and must be backed by the resources and political will that can make them effective.

Unless we act, stories like Ryan Harrison's and Abe Davis's will remain nothing more than happy exceptions.

Conclusion

Thank you for your efforts to strengthen American competitiveness. If we at Johns Hopkins can assist you in this important endeavor, please do not hesitate to contact us. I invite you and your staff to visit our campuses, explore our facilities and meet our researchers face-to-face. You will find no more persuasive argument for the inestimable value of investment in research than witnessing the innovative enterprise firsthand.

Senator ENSIGN. Thank you.

Dr. Pietrafesa? Am I saying that right?

Dr. PIETRAFESA. Pietrafesa, yes, sir.

Senator ENSIGN. Very good.

Dr. PIETRAFESA. Yes.

STATEMENT OF DR. LEONARD J. PIETRAFESA, ASSOCIATE DEAN, PROFESSOR OF OCEAN AND ATMOSPHERE SCIENCES, NORTH CAROLINA STATE UNIVERSITY; CHAIR, SCIENCE ADVISORY BOARD, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

Dr. PIETRAFESA. Thank you very much, Chairman Ensign, for inviting me to testify.

In the late 1930s, at a time when the government did not fund basic research, Alfred Loomis, a wealthy New York industrialist and science geek, was the benefactor of basic research pursuits of the world's foremost scientists and mathematicians. One of the scientific breakthroughs that he fostered led to the development of microwave radar. Mr. Loomis contacted President Roosevelt. An enormous mismatch in capabilities resulted between the Allies and the Axis. This is an example of a basic scientific breakthrough that, to great measure, is responsible for the position in the world order that the U.S. has enjoyed since World War II.

This story both inspires and saddens my father, a World War II veteran seriously injured in Europe. He is enormously proud of what the United States accomplished by saving the world. Now, in his 90th year, he fears for the economic future of the U.S. because of what he perceives as misguided government spending priorities. "Why aren't we leading the world in new discoveries like we used to?" he asks. I cannot answer this question.

Speaking of radars, in 1918 a flu epidemic killed 100 million people in 24 weeks. We—now, we may be facing the avian flu, but we have the NOAA Weather Service National Radar Network in place. Buried within the weather radar archives are the signals of flocks of birds. Statisticians, radar meteorologists, and ornithologists could mine the data and determine the likely pathways of migratory birds to spread the flu virus, and, thus, provide an advanced warning system for the Nation.

Space weather research and forecasting is a jewel at the NOAA Space Environment Center. Sun storms interfere with the normal operation of communications, and can cause large-scale blackouts. Without basic research advances in space weather, the Nation's readiness, transportation, commerce, and competitiveness will be severely compromised.

Autonomous undersea vehicles, unmanned aerial vehicles, remotely operated vehicles, and marine buoys would all be greatly enhanced with more durable sensors and greatly reduced payloads via NSF- and DOD-funded nanotechnology advances. The vehicles could fly in and out of hurricanes, through the waters below the hurricanes, and in noxious atmospheric plumes and harmful algal blooms, a very attractive operational possibility.

Recently, a NASA scientist developed a new mathematical method to process nonlinear data in his basic research, and opened up an entire new field of data analysis. He was elected to the National Academy. However, the scientist has chosen to retire from NASA, and will join a university in Asia, where the success rate for research proposals is 80 percent, versus U.S. rates. The U.S. has lost a National Academy member to a foreign country because of scarce U.S. research dollars.

The area of basic research and the understanding of how the atmosphere, ocean, and Great Lakes interact is extremely important in forecasts of our weather and climate. But the 140 marine buoys that collect data in the Nation's coastal waters is an order of magnitude too low to properly conduct research or to do proper data simulation.

Here, the NOAA Science Advisory Board has strongly endorsed the Integrated Ocean Observing System, IOOS, put forward by the U.S. Commission on Ocean Policy. The sustained IOOS could be managed by NOAA, in partnership with the university community.

Coupling global climate to regional to local scale models is a significant physical, mathematical, and cyberscience challenge, all highly computationally-intensive. The research community needs next-generation national computing facilities that can be accessed broadly by U.S. scientists so that community models can be run and our Nation's knowledge-base extended.

NOAA is the leading environmental mission agency for the U.S. It is responsible for environmental observing systems and networks, environmental management, and operational forecasting. If NOAA were to disappear today, you would have to recreate it tomorrow. It was NOAA, working as a team, that enabled the delivery of accurate and timely information regarding the impending landfall of Hurricane Katrina, a forecast that saved tens of thousands of lives; albeit, this forecast was a result of 20 years of prior research.

The SAB recognizes the extraordinary fiscal constraints and difficult choices the Subcommittee must make. However, we have no birthright to global economic leadership and a high standard of living. These are things that we have to continue to earn. So, thus, the investments must be made. And many of the possibilities that I alluded to earlier require funding.

In the case of NOAA, that would be to support a \$4.5 billion appropriation for FY07. This would address research initiatives, such as I mentioned, in areas of priority traditionally supported by the Senate, all focused on U.S. competitiveness and leadership. And, incidentally, coupling the physical, mathematical, statistical, life, health, socio, and economic sciences is, of itself, a basic research challenge.

Thank you for the opportunity to provide this statement.

[The prepared statement of Dr. Pietrafesa follows:]

PREPARED STATEMENT OF DR. LEONARD J. PIETRAFESA, ASSOCIATE DEAN, PROFESSOR OF OCEAN AND ATMOSPHERE SCIENCES, NORTH CAROLINA STATE UNIVERSITY; CHAIR, SCIENCE ADVISORY BOARD, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

A hearing on: the Importance of Basic Research to United States Competitiveness— The hearing is intended to explore how basic research in the physical sciences impacts both long-term economic development in the United States and the ability of American industry to remain globally-competitive.

Mr. Chairman and members of the Subcommittee, I am pleased to submit this statement in strong support of the role of basic research to United States competitiveness.

My name is Len Pietrafesa, and I am an Associate Dean and a Professor of Ocean and Atmospheric Sciences in the College of Physical and Mathematical Sciences at North Carolina State University. I also serve as Chair of the National Oceanic and Atmospheric Administration's (NOAA) Science Advisory Board.

The NOAA Science Advisory Board (SAB) was established by a Decision Memorandum dated 25 September 1997, and is the only Federal Advisory Committee with responsibility to advise the Under Secretary of Commerce for Oceans and Atmosphere on long- and short-range strategies for research, education, and application of science to resource management and environmental assessment and prediction. SAB activities and advice provide necessary input to ensure that National Oceanic and Atmospheric Administration science programs are of the highest quality and provide optimal support to resource management. The SAB consists of 15 members with backgrounds and expertise ranging across the spectrum of NOAA's mission responsibilities.

I would like to thank the Chair of the Committee, Senator Stevens for inviting me to testify. This is truly an honor to be offering testimony, along with Dr. J. Marberger, Dr. A. Bement and Dr. W. Jeffreys.

More than seven decades ago, Dr. James B. Conant, former President of Harvard University and a chemist by profession, said "to advance scientific knowledge, pick a man (or woman) of genius, give him (or her) money and leave him (or her) alone" (parentheses added). While the paradigm has changed since then, Dr. Conant had a colleague, Mr. Alfred L. Loomis, a retired wealthy industrialist and a science geek, who in the 1930s, through his vast fortune, became the patron and benefactor for basic scientific pursuits to the world's foremost scientists and mathematicians of the 1930s (e.g., Bohr, Compton, Einstein, Fermi, Heisenberg). These studies were conducted in the then state-of-the-science and technology laboratory that Mr. Loomis constructed in his massive Tuxedo Park, New York mansion. This was a time when the government did not fund basic research. One of the subsequent scientific breakthroughs that he and colleagues Dr. E. Lawrence, a Berkeley physicist, Dr. R. Varian of Stanford, and others from the RadLab of the Massachusetts Institute of Technology led to the development of microwave radar. Realizing what he had in his laboratory, Mr. Loomis contacted President F.D. Roosevelt, who contacted Prime Minister W. Churchill. At that time, the Axis did not have microwave radar but in short order the Allies surely did. An enormous mismatch in capabilities was affected. This is an example of a basic scientific breakthrough that led to a technological advance that to great measure is responsible for the position in the world order that the U.S. has enjoyed since WWII.

This story both inspires and saddens my father, a WWII veteran seriously injured in Europe, who is enormously proud of what the United States accomplished by "saving the world" but who now in his 90th year, fears for the economic future of the U.S. because of what he perceives as "misguided government spending priorities." "Why aren't we leading the world in new discoveries, like we used to," he asks.

Speaking of radars, in 1918 a flu epidemic broke out and killed 100 million people globally in 24 weeks; more than had died in over a century of the Black Plague. Now we may be facing another global pandemic, the Avian Flu. But in the U.S. we have a national network of radars that was funded by a prior Congress and is managed by the Department of Commerce's National Oceanic and Atmospheric Administration's Weather Service. Buried within the weather radar signal archives are the signals of flocks of birds. So, could mathematicians, statisticians and radar meteorologists apply methodologies to mine the radar data and figure out what the likely pathways that migratory birds might be to spread the flu virus across North America? Sure, why not. Basic research in mathematical and statistical methodologies

and radar science could conceivably provide an advanced warning system. What will the value of this prior knowledge be worth to the health and the economy of the Nation? The point is that the investments made by this Congressional body in the modernization of the NOAA Weather Service over the past two decades could undergird and enable new research that will couple the physical, mathematical, health and social sciences and result in saving American lives.

Given the new lives that most of us and all of our children and grandchildren will lead, via the Internet, it should be remembered that the Internet was derived from Arpanet (which was funded out of DARPA for the purpose of defense contractors communicating and exchanging technical reports) and other standalone networks such as Omnet which was created by oceanographers (with funding from the Office of Naval Research and the National Science Foundation, so that these scientists could communicate with each other); a basic, fundamental advance in communications that has created new jobs, new industries, new products and services and led to the virtual flattening of the World; all in the relative blink of an eye. Have you used www.gotomeeting.com? Try it, you'll love it.

The U.S. is the hub of global networks and communications. Space weather research and forecasting is a scientific and technological jewel at the NOAA Space Environment Center in Boulder, CO. Space weather describes (<http://www.sec.noaa.gov/>) the conditions in space that affect Earth and its technological systems. Space weather is a consequence of the behavior of the Sun and the nature of the Earth's magnetic field and atmosphere. Solar disturbances categorized in space weather terms are: Radio Blackouts, Solar Radiation Storms and Geomagnetic Storms. These storms interfere with the normal operation of communications used by airlines and emergency response teams, military detection and early-warning systems, global positioning systems (GPS) which control the spatial referencing network, satellite components and spacecraft operations. Solar storms also have the potential to impact power transformers, cause large-scale blackouts in North America, and also create a biological threat to both astronauts and people flying in aircraft. Basic research in the physical, mathematical and statistical sciences is very important in space weather and without the advances made and hopefully to be made, U.S. competitiveness would be severely compromised. The mathematics of the plasma physics of "space weather" is daunting and one cannot design the experiments, they come pre-designed so there are no options. They are dealt with on the fly.

As an example of mathematical enabling in experimental design, the SAS Institute in Cary, North Carolina, the world leader in data analysis software, with billions in annual revenues, had its origins with a group of North Carolina State University researchers, Drs. Goodman and Saul, focused on the statistics of experimental design. The researchers made some breakthroughs in statistical methodologies and formed a company. These advances have resulted in a strongly competitive, well run U.S. corporation (featured on CBS's "60 Minutes"). The software itself is used to deliver decision-support such as data mining to help other companies make more informed choices.

In the arena of experimental design for quality improvement, carefully constructed settings for factors that affect production allow the maximum information extraction for a given amount of experimental effort. For example, a grinding experiment to efficiently create an optical lens (like an eyeglass), with 12 factors (like wheel speed, grit size, etc.) each of which can be at a high or low level, would require 2048 runs to see the effect (on say, surface roughness) for every combination of the 12 factors. But through the magic of statistical optimization, a carefully designed experiment would require only 192 runs for all factors. This is an incredible shrinking in an economy of scale resulting in huge savings to the optical industry.

Another area of basic statistical research is in "anomaly detection," whereby statistical methods have been utilized to discover hot spots of activity, such as disease outbreaks, a topic of current basic research. Also methods for automatic flagging of unusual or outlier values and methods of detecting change points in data taken over time have potential not only for controlling manufacturing processes but might be used in a homeland security context and in environmental data assessment. This approach would be valuable for flagging outliers, unusually extreme or potentially bad data, as these data are streaming in; such as data transmitted in real-time from the NOAA Weather Service national monitoring network or the upcoming Department of Defense (DOD) and NOAA NPOESS Satellite constellation. Terabytes (or petabytes?) of data must be evaluated on the fly and the results of basic statistical research could provide new methodologies to evaluate the trillions (or 10s thereof) of points of data on the fly; thus ensuring that the multi-billion dollar investment of this Congress in our needed satellite systems (*e.g.*, NOAA GOES and the DOD/NOAA NPOESS) yields maxima benefits in data utilization.

To paraphrase a popular ad campaign, you could say that statisticians don't make the decisions; they make the decision process better. Basic research in statistics provides tools just as a violin maker provides an instrument rather than making the music. One cannot play beautiful music without a well crafted instrument made for that purpose.

How about Nano-Science? Here are some recent headlines and universities involved:

- Nanotechnology Find and Treat Breast Tumors, Dec. 12, 2005, *Nanotechwire*—Rice University physical scientists offer enticing insights into how these minute particles can be manipulated to have different properties, and tagged with antibodies to target them specifically at cancer cells.
- Nano for Brain Cancer Imaging, Treatment Nov. 14, 2005, *Small Times/Richmond Times—Dispatch*—University of Virginia researchers are loading tiny, hollow carbon balls with metals and medicine to detect and destroy brain-cancer cells.
- Nanoparticles Create Anti-fog Coating Sep. 7, 2005, *Nanotechweb*—Massachusetts Institute of Technology (MIT) researchers have devised a silica nanoparticle coating that causes water droplets to flatten into a thin uniform sheet rather than form the usual annoying light-scattering beads eliminating fog on windows, spectacles and other glass surfaces.
- Carbon Nanotube Sheets Aug. 18, 2005, *PhysOrg*—University of Texas at Dallas scientists have produced transparent carbon nanotube sheets that are stronger than the same-weight steel sheets and have demonstrated applicability for organic light-emitting displays, low-noise electronic sensors, artificial muscles, conducting appliques and broad-band polarized light sources, switched in one ten-thousandths of a second.
- Nanotubes For Healing Broken Bones Jul. 8, 2005, *Science Daily*—University of California Riverside physical scientists have shown that carbon nanotubes make an ideal scaffold for the growth of bone tissue allowing doctors to inject a solution of nanotubes into a fracture for healing.
- Nanotechnology and Hydrogen, Mar. 29, 2005, *Eurekalert*—Rutgers scientists are using nanotechnology in chemical reactions that could provide fuel for tomorrow's fuel-cell powered clean energy vehicles.

Thank you NSF, and the DOD research arms for sponsoring pioneering basic research in "nano" science and technology. This basic research will enable all other areas of "S&T". Still, much more of an investment is needed. And the paybacks to society will be great.

Instruments and sensors deployed in or above the ocean environment are often at risk due to high winds, waves, currents, sea spray, bio-chemical fouling and the marine transportation community not to mention the occasional presence of humans. To that end, nanotechnology may have much to offer in the development of more reliable and durable sensors and instruments. As a corollary, the same technology might advance the state of observing science in the atmosphere. Measurements made from moving vehicles, such as autonomous undersea vehicles, Unmanned aerial vehicles and remotely operated vehicles would all be greatly enhanced with more durable sensors and greatly reduced payloads. Data gathering by flying in and out of hurricanes and through the waters below the hurricanes via unmanned vehicles is a very attractive operational possibility. Likewise for noxious atmospheric plume events. The U.S. Department of Energy (DOE) supported a robust atmosphere and ocean instrument development program that was especially visionary and produced many of the off-the-shelf ocean instruments that are available today. The DOE Brookhaven National Lab, the Woods Hole Oceanographic Institution, the University of Washington, Texas A&M University and many other institutions, advanced the state of technology and science with funding from DOE in the 1970s, 1980s and mid-1990s. That DOE program no longer exists. But basic research is still needed in all of the above areas. Perhaps NOAA could be the facilitating agency.

Speaking about the environment, can basic physical and mathematical sciences research be conducted on environmental topics that are of value in the competitive position of the U.S.? The answer is a resounding "yes". Examples and some challenges are given below.

The long-time series of basic state environmental variables constitute our climate record; generally difficult to decompose and understand. Albeit, a National Aeronautics and Space Administration (NASA) scientist/mathematician developed a new mathematical empirical methodology in his studies of the fluid mechanics of water waves and in the process of doing this basic research, has opened up an entire new

field of data analysis, for which he was elected to the National Academy. This advance has enabled new breakthroughs in voice recognition, aircraft wing deterioration, etc. Colleagues and I have used this empirical methodology to determine that the modern rate of sea level rise is the second fastest over the past 18,000 years, and that the frequency of occurrence of hurricanes in the North Atlantic has 3–5, 10–12, 25–30 and 45–55 year modes of variability. So there are enormous implications for climate studies to be derived from the mathematical breakthrough of this NASA scientist. Incidentally, the NASA scientist was recently informed by NASA that he needed to acquire more non-NASA sponsored research dollars, at a time in the U.S. when basic research dollars are more difficult to obtain. So he has chosen to retire from the agency and to accept an offer to join a university in Taiwan where the success rate for proposals is closer to 80 percent vs. the U.S. NSF rate which is presently 10–20 percent and in which a reported \$2B of proposals rated “excellent” went unfunded last year. The U.S. has lost a National Academy member to a foreign country because he can no longer afford to pursue the funding for basic research in the U.S.

The development of “empirical orthogonal functional” (EOF) analysis in the 1950s by an MIT physicist was an important mathematical advance. This analysis has recently been used in the development of a hurricane land-fall forecast capability. In the NOAA (National Environmental Space & Data Information Service and National Ocean Service) sponsored cooperative Climate and Weather Impacts on Society & the Environment (CWISE), scientists at North Carolina State University combined EOF analyses of past hurricanes and tracks with statistical regression, and are able to predict several months in advance, the number of hurricanes most likely to strike the Gulf/Caribbean and U.S. East Coasts. The 2006 forecast for the East Coast is due on 01 April and the Gulf on 01 June.

A scientist from Columbia University was studying plate tectonics off of the coast of Asia using an acoustic sound array in December 2004. He discovered that the acoustic signals generated by the 26 December undersea earthquake that resulted in the tsunami that killed several hundred thousand people in Sri Lanka, India and Phuket without warning are evident in his data archive. The key here is that the speed of sound in water is 1,500 meters/second while the speed of the tsunami wave itself is more like 200 meters/second. So the warning of an approaching tsunami can be delivered in $\frac{1}{7}$ the time using acoustic devices. This is a serendipitous finding in an all-together unrelated basic research project funded by NSF.

In the early 1980s an air-sea monitoring network was deployed along the equator in the Pacific Ocean. Development of the Tropical Atmosphere Ocean (TAO) array was motivated by the 1982–1983 El Niño event, the strongest of the century up to that time, and not detected until nearly at its peak. The event highlighted the need for data from the tropical Pacific for an improved understanding of the El Niño Southern Oscillation (ENSO). So a modest array was deployed to assess how these enigmatic events occurred. What we learned was that ENSO was well structured and affected climate and weather patterns globally; thus agriculture, fisheries, the global supply of protein, landslides in California and so on. Again, basic research in mathematics and computational science and in the technological development of related monitoring and computational instrumentation has resulted in huge leveraging for U.S. industries in the global marketplace. Today, there are 70 moorings in the TAO array and NOAA makes seasonal forecasts of atmospheric state variables for the U.S. based on the disposition of ENSO.

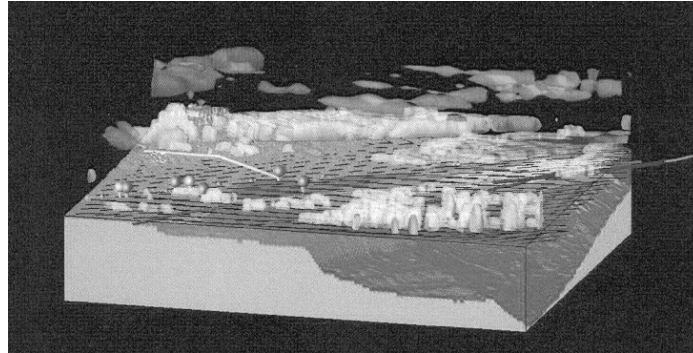
The area of basic research in the understanding of how the atmosphere and oceans exchange heat, buoyancy, energy and momentum is extremely important for environmental prediction; such as understanding the causes of and forecasts of our weather and climate. We are learning a great deal in university laboratories, on NSF, ONR and NOAA field expeditions and by using high-performance computing for better data collection and analysis. What are the potential benefits of this research? Well, what is the value of better forecasts of atmospheric storms with heavy precipitation, snow, ice and rain, annually? The ski and snowboarding industry cannot prosper without snow and they need to plan well in advance to anticipate what the upcoming season holds in store. Water managers need this information seasons in advance because they need to plan for upcoming allocations; overages and shortfalls. Emergency managers, the highway patrol and power companies need to know where precipitation will fall, how much, in what form and when and whether or not flooding will occur. The average annual costs of snow storms alone to the U.S. are: removal ~ \$3B; road closures ~ \$20B; flight delays ~ \$4B; public utilities ~ \$2B; and flooding from snowmelt ~ \$6B; a total of \$35B annually. And agricultural crop and timber damage can be up to \$2B/ice storm. The cost of flooding to the U.S. in 2005 will likely total more than \$300B. OK, so 2005 was an unusual year with Katrina, Rita and 25 additional tropical cyclone events. Or was it? More climate research will

reveal the rest of the story. Unfortunately there are presently too few observing systems that monitor air-sea interactions and thus the basic research that can be conducted on two fluid interactions is seriously limited.

How good are we at forecasting precipitation, rain, snow and ice? Well the NOAA NWS National Centers for Environmental Prediction (NCEP) does a good job, considering the data available to initialize and be ingested and assimilated into NOAA NCEP models. But it could be better. It could be vastly improved with better information available in real time. There are but ~ 140 marine buoys that collect air and near surface water temperatures and provide those data in real time, around the Nation's coastal waters including the Atlantic, Pacific and Gulf Coasts, the Great Lakes, Alaska and Hawaii. Is that coverage adequate? The short answer from those of us who do ocean-atmospheric coupled fluid research is "no". The coverage is an order of magnitude too low.

Here is an image of a two-way interactively coupled atmospheric and ocean numerical model system output that shows a winter storm, a "nor'easter" forming off the Carolinas coast in 1996. The white represents clouds, green is rain, pink is ice and purple is snow.

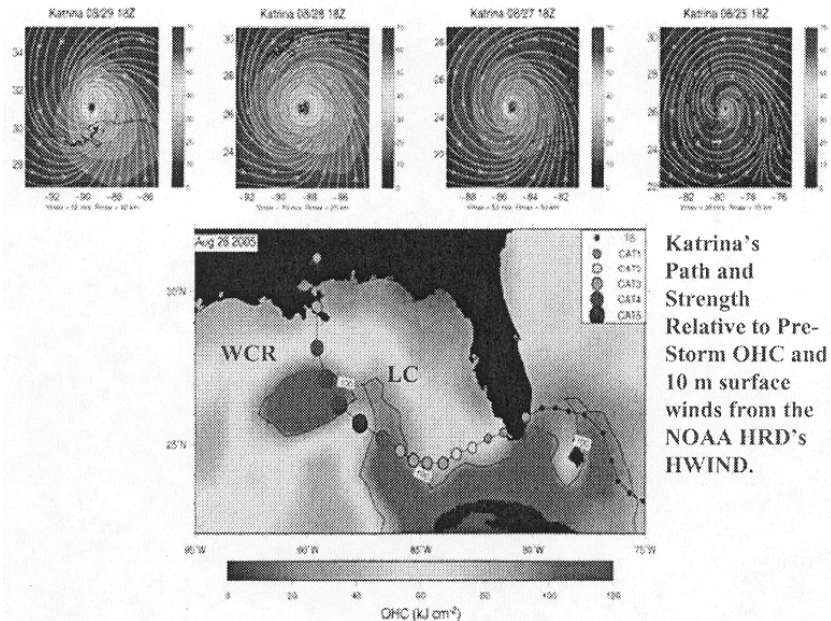
The total of each can be estimated by integrating across the volumes of each form of precipitation. How valuable is it to DC, MD, PA, NJ, NY, CT, MA, MN, etc. . . . to know these numbers ahead of time?



In this entire storm area stretching from S.C. to the VA border, there are only three permanent coastal NOAA National Data Buoy Center buoys providing air-sea information. The red dots are new observing sites in a NOAA National Ocean Service-sponsored program called the Carolinas Coastal Ocean Observing and Prediction Program, led by the University of South Carolina, presently extending from southern S.C. to southern N.C. However, the average centroids of these storms tends to be closer to Cape Hatteras, N.C. well to the north, near the yellow-green patch shown in the storm, so more sites are needed to the north. The reason that this 1996 storm model output is so robust is that there were 29 ocean-atmosphere university research (DOE and NSF-sponsored) moorings in the region at the time of the storm and the assimilation of these data into the model greatly improved our ability to more properly hind-cast the storm. The conclusion: a greatly expanded observing network is needed to make better weather predictions, over the ocean, along the coasts and over land. Why: to better understand very complex, air/sea interactive couplings. This is basic research to a scientist like me. The value: greatly improved forecasts of the type and quantity of precipitation in a storm, improvements in storm track forecasting, improvements in forecasts of ocean current and wave fields, improved forecasts of where and how much coastal erosion, coastal mass wasting, inlet migration and new inlet formation will occur, and so on. By the way, the program alluded to in the winter storm figure shown above was the last of the DOE sponsored field expeditions and modeling programs linking the atmosphere to the ocean, coastal ocean and estuaries and rivers of the U.S. It ended in 1997. It was responsible for enormous advances in new instrumentation, new science and new scientists and was worth every dollar of investment by Congress.

Is the story any better for the modeling of hurricanes in transit; especially the potential interaction of the hurricane with the ocean beneath it? Do exchanges between the air in hurricanes and water masses below serve to further intensify or to de-intensify the intensity of the wind-field of the hurricane? The figure below (from University of Miami and NOAA Hurricane Center scientists) suggests this may well be the case. Katrina was more intense over warmer waters and less in-

tense over cooler waters. In the Spring 2005, Undersecretary of Commerce for Oceans and Atmosphere, VAMD C.C. Lautenbacher, requested that the NOAA SAB commission a study of wind intensity forecasting for hurricanes. The external evaluation is in progress.



The NOAA SAB has strongly endorsed the Integrated Ocean Observing System (IOOS) put forward by the U.S. Commission on Ocean Policy. These observations offer critical information not only for atmosphere and ocean and Great Lakes interactions but also on coastal processes necessary for addressing issues, such as the health of humans and marine life, broadly defined weather and climate now-casts and forecasts, homeland security, and resource management. Coastal and marine laboratories have been at the forefront in addressing this need. However, funding for existing subsystems is difficult to sustain, and significant additional funding is required to implement the national integrated system. Although efforts have been made in the past to coordinate Federal agencies involved in ocean and coastal research and national and international programs regarding coastal, ocean, and Great Lakes observing systems, further investment and strengthened cooperation at all levels is still needed to ensure that these systems are sustained and that they incorporate the long-term monitoring efforts of the Nation's coastal and marine laboratories. The SAB, and both marine and atmospheric science organizations, enthusiastically support the development of a sustained IOOS to be managed by NOAA. Attached to my testimony is a copy of a "community generated" resolution endorsing IOOS. However, the university community has an important role to play in that it can conduct basic research on data recovery, data quality assessment, data assimilation into models, data mining and coupled model architecture.

The examples above lead the SAB to strongly support enhanced funding for ocean, atmospheric, coastal, and Great Lakes basic research in the physical and mathematical and other natural sciences, the social sciences, education, outreach, and related infrastructure. Part of the basic research challenge is the connecting of the physical sciences through the life sciences and to the social and economic sciences. This *per se* is a very challenging research topic that must be resolved if science is to properly serve the various sectors of U.S. society and ensure that the U.S. will be globally competitive.

Improving our knowledge of the ocean, atmospheric and hydrologic sciences has much to offer the Nation as it seeks to strengthen its ability to innovate and compete in today's global economy. These sciences are inherently interdisciplinary, push the envelope in terms of technology development, test the boundaries of our data collection and analysis systems, and offer an effective training ground for future sci-

entists, mathematicians, statisticians and engineers; particularly in a setting of working as a team. As the Nation seeks to augment its investment in the physical and mathematical sciences to increase its international competitiveness, the SAB calls on policymakers to recognize the integrated nature of the environmental sciences, particularly the ocean and atmospheric sciences and to support an enhanced investment in these as well as other science and engineering disciplines as part of any long-term economic competitiveness policy.

Human and environmental health are critical factors in the quality of life of the citizenry of the society of the U.S. NOAA has and is conducting and supporting important research in such areas as atmospheric chemistry tracking and forecasting, coastal eutrophication monitoring and modeling, remote detection and monitoring of emissions or other airborne contaminants, marine debris detection and source tracking, and development of technologies to detect and predict the pathways of oil spills and harmful algal bloom outbreaks.

The SAB supports increased Federal funding for the National Science Foundation (NSF) consistent with the President's budget for FY 2007. Basic research and the transfer and use of the knowledge developed through research are vital for the long-term economic competitiveness and national security of this Nation. It is increasingly important for the Nation to maintain and enhance its scientific edge in a global community with emerging new capacities for scientific research. NSF provides vital support for basic research and education which enhances public understanding of the atmosphere, oceans, coastal areas, and the Great Lakes. NSF also provides important support for basic laboratory facilities, instrumentation, support systems, computing and related cyber-infrastructure, and ship and aircraft access. The final report of the U.S. Commission on Ocean Policy makes recommendations on the need to develop and enhance ocean, coastal and Great Lakes research infrastructure; including research vessels, ocean observing systems, and the shore-based instrumentation and equipment needed to collect and analyze the data and observations made by research vessels and the observing systems. Additionally, kids are science geeks and the physical and environmental sciences are great vehicles to ride to ensure a scientifically, technologically and environmentally literate future U.S. society.

NOAA is the lead operational environmental mission agency for the U.S. NOAA maintains the Nation's environmental weather and climate observing networks, oversees environmental management and is responsible for operational environmental forecasting. It provides decisionmakers with important data, products and services that promote and enhance the Nation's economy, security, environment, and quality of life. It was NOAA, and its underlying science enterprise, that enabled the delivery of accurate and timely information regarding the impending landfall of Hurricane Katrina in 2005, a forecast that saved tens of thousands of lives. While that forecast could be cast as the result of "applied research," in point of fact, the ability to model the hydrodynamics and thermodynamics of an anti-symmetric vortex, moving through and interacting with larger scale and smaller scale atmospheric systems and interacting in real time, over compatible spatial and temporal scales, with a moving interactive body of water that has its own boundary current and eddies, was and remains a basic research challenge.

Moreover, the ability to quality assess, ingest and assimilate satellite data, ocean buoy data and aircraft data into the models is of itself a mathematical research challenge. The competitive position of the Nation must be viewed not only on positive advances and successes but also on the role of science in advancing fundamental knowledge to the point of leading to success in reducing the negative impacts that environmental events can have on the Nation's economy. Basic science, conducted to a significant degree by university scientists external to NOAA, has led to improved forecasts within NOAA. This science was conducted over several decades and melded together creatively by NOAA scientists to meet the agency's mission needs.

For that reason, the SAB supports a \$4.5 billion budget for NOAA in FY 2007 for NOAA. As suggested by an ad hoc coalition of NOAA stakeholders, this amount would fully fund the President's FY 2007 budget request, restore funding for core programs, and address all the areas of concern and priority that have traditionally been supported by Congress. It would allow enhancements in the development of an integrated ocean and atmospheric observing system; increased research and education activities and expanded ocean conservation and management programs; and provide critical improvements in infrastructure (satellites, ships, high-performance computers, facilities), and data management. It would allow the external university community to conduct the basic research that will lead to improved forecasts by the agency.

In August 2004, a Congressionally-requested study of NOAA's research programs, entitled, *Review of the Organization and Management of Research in NOAA* con-

cluded that extramural research is critical to accomplishing NOAA's mission. The access to such enhanced research capacities provides NOAA with world-class expertise not found in NOAA laboratories; connectivity with the planning and conduct of global science; means to leverage external funding sources; facilitation of multi-institution cooperation; access to vast and unique research facilities; and access to graduate and undergraduate students. Academic scientists also benefit from working with NOAA, in part, by learning to make their research more directly relevant to management and policy. It is an important two-way interaction and exchange of information and value.

Climate and long-range weather prediction are substantial basic science challenges. Coupling global climate models to regional scale models at the appropriate scales of temporal and spatial variability are significant physical, mathematical and cyberscience challenges. The couplings must properly include all components of the Earth system, the atmosphere, the oceans, ice and terrestrial components. The couplings must be capable of being downscaled, from larger spatial and temporal scales to smaller scales and upscaled (from smaller to larger). But this is computationally demanding. The university community and the NSF-sponsored National Center for Atmospheric Research anxiously await next-generation national computing facilities that can be accessed broadly by U.S. scientists so that community models can be run and our Nation's knowledge-base extended. Business, industry and the military await the further development of this fundamental, basic research. The future competitiveness of the U.S. will depend to great degree on the outcome of what these studies show for the future climate of the U.S. and other countries throughout the world.

The SAB strongly supports a robust NOAA extramural research activity and calls on the Senate Subcommittee on Technology, Innovation, and Competitiveness to support the NOAA's Ocean and Atmospheric Research programs, including the National Sea Grant Program, the Ocean Exploration Initiative, a true venture into the great ocean abyss on our planet, the National Undersea Research Program which Ocean Exploration will embrace, as well as research related to aquaculture, invasive species, harmful algal blooms and the various joint and cooperative institutes at levels envisioned in last year's Senate version of the Commerce-Justice-State Appropriations bill. These partnership programs are not only consistent with the findings of the Congressionally-mandated August 2004 review of NOAA research, but are also consistent with the NOAA strategic plan and enable NOAA to carry out its mission at state and local levels.

The SAB strongly supports implementation of the recommendations from the U.S. Commission on Ocean Policy (COP) and the initial efforts of the Administration's Interagency Committee on Ocean Policy to develop a response to COP's recommendations. COP's analysis of policies governing oceans, coasts, and Great Lakes has resulted in a collection of bold and broad-reaching recommendations for reform. Implementation of these recommendations by the Federal Government will enable the U.S. to maintain and strengthen its role as a world leader in protecting and sustaining the planet's oceans, coasts, and Great Lakes. The SAB is particularly supportive of COP's recommendation to double the Federal investment in ocean, coastal, and Great Lakes research as well as its recommendation to promote a strong Federal investment in ocean, coastal, and Great Lakes education, outreach, and stewardship and in IOOS.

By any measure, basic scientific research has made monumental contributions to technology and to the national priorities of the U.S. The bond between basic research and the development of both novel and current technologies has been and is well in place. Science and U.S. society must continue to co-evolve. The nature of this evolution will certainly be affected by the extent to which this Senate sets funding priorities. Hopefully this Senate will recognize that the dependence of the development of successful novel technologies on broadly supported basic research will lead to a future Nation that is healthier and more economically prosperous than at present. Because of the unpredictability of the details of the new science and technology that will evolve, the details of social evolution are also unpredictable. But the future health and prosperity of this Nation are inextricably coupled to the investments made in basic research today.

We see that we have no birthright to global economic leadership and a high standard of living. These are things that we have to continue to earn. The pressures and opportunities are relentless and inexorable. At the core of these unprecedented challenges, is the requirement for the highest caliber of human capital, the need for us to educate and challenge students to push the limits of innovation, technology and discovery. We need national commitments to drive advancements in energy, health, environment, food safety, security, solutions to world poverty and much more.

The SAB recognizes the extraordinary fiscal constraints and difficult choices the Subcommittee must make. Nevertheless, the research and education programs under the Subcommittee's jurisdiction are vital investments in the future of this Nation and deserve the maximum support possible. Thank you for the opportunity to provide this statement.

APPENDIX: COMMUNITY RESOLUTION ON INTEGRATED OCEAN OBSERVING SYSTEM (IOOS)

Endorsed by the Coastal States Organization, Consortium for Oceanographic Research and Education, National Estuarine Research Reserve Association, National Federation of Regional Associations for Coastal and Ocean Observing, U.S. Chamber of Commerce Space Enterprise Council

Recognizing that the oceans and coastal waters affect all our lives—driving weather and storms, influencing climate, providing transport for millions of tons of cargo, and sustaining coastal and marine resources.

Further Recognizing that more than a century ago, the United States began creation of a comprehensive weather forecasting and warning system and today, daily weather reports are central to the Nation's social, economic, and environmental vitality.

Acknowledging that the Nation's coastal regions, including the Great Lakes, are home to more than half the Nation's population, but lack basic information to protect those communities and their environment, to track, understand and predict change, and to provide quality information to those who work on or near the water.

Understanding that deployment and operation of a sustained Integrated Ocean Observing System will: (1) improve the safety and efficiency of marine operations, (2) improve prediction of weather and natural hazards (including tsunamis and storm surges) to reduce resulting damages and costs, (3) improve predictions of climate change and its socio-economic consequences, (4) improve national security, (5) reduce public health risks, (6) help protect and restore healthy ecosystems, and (7) sustain and restore living marine resources.

Aware that many elements of a national system are already in place, but most now operate independently, the IOOS would combine these elements into interconnected global and coastal components. The global component focusing on the physical observations associated with climate and weather prediction, including tsunami detection. The coastal component, comprising a Federal "national backbone" of observations and data management and regional coastal observing systems, addressing the complex physical, chemical, and ecological observations needed to assess and manage coastal regions.

Further aware that the national backbone and regional associations must work closely with end-users—including state and local governments, nonprofit organizations, industry, and citizens—to identify and meet their needs and to build partnerships that facilitate the opportunity for them to participate and invest in the observing system.

Affirming that implementation of the IOOS system will require a substantial sustained investment in research, pilot projects, and related infrastructure to develop new data products and system enhancements and incorporate new technologies into the system.

Cognizant that the United States and the world are facing critical decisions about the future stewardship and management of the oceans, coastal waters, and fresh water resources, including the Great Lakes and improved data and predictions resulting from the IOOS is needed to support these decisions.

Our organizations resolve that we are committed to the development of an ocean and coastal observing network endorse the following:

An integrated ocean observing system should include:

- (a) A national program to fulfill national observation priorities, including marine commerce and the Nation's ocean contribution to the Global Earth Observation System of Systems and the Global Ocean Observing System.
- (b) A network of regional coastal and ocean observing and information programs that collect, measure, and disseminate data and information products to meet regional and national needs, managed by certified regional associations.
- (c) The designation of the National Oceanic and Atmospheric Administration as the lead Federal agency for implementation and administration of the system.

(d) An Interagency Program Office within the National Oceanic and Atmospheric Administration that is responsible for program planning and coordination of the observing system.

(e) Data management, communication, and modeling systems for the timely integration and dissemination of data and information products from the national and regional systems.

(f) A sustained research and development program to advance knowledge of coastal and ocean systems and ensure improvement of operational products, including related infrastructure and observing technology and large scale computing resources and research to advance modeling of coastal and ocean processes.

(g) A coordinated outreach, education, and training program that integrates and augments existing programs to ensure the use of data and information for improving public education and awareness of the Nation's coastal and ocean environment and building the technical expertise required to operate and improve the observing system.

(h) Data products and information that meets the needs of end-users—including state and local governments, nonprofit organizations, industry, and citizens.

Action either by Executive Branch and/or Congress to establish an integrated national system of ocean, coastal, and Great Lakes observing systems to address regional and national needs for ocean information.

Senator ENSIGN. Thank you.
Mr. Ritter?

**STATEMENT OF PHILIP J. RITTER, SENIOR VICE PRESIDENT,
PUBLIC AFFAIRS, TEXAS INSTRUMENTS**

Mr. RITTER. Thank you, Chairman Ensign. I appreciate the opportunity to testify today.

TI celebrated our 75th anniversary last year. And we're a company that has grown and thrived on innovation and investments in research. The competitiveness agenda is our highest public priority—public-policy priority. We see this issue of investing in basic research, along with STEM education and access to top graduate-level talent coming out of our engineering and computer science schools, as the most important priorities.

If I may, I'd like to provide an example of the power of investment in basic research and its direct tie to economic development in this Nation.

Three years ago, TI had a \$3 billion decision to make as to where we would locate our next-generation semiconductor manufacturing facility. And we looked at numerous sites around the world, many of which offered very attractive economic incentives, as well as research partnerships. We decided to locate this facility in Richardson, Texas. And, when it's fully operational, it'll create over 1,000 direct jobs and have a tremendous impact on the regional and national economy.

And I would be remiss if I didn't thank you, Mr. Chairman, for your work on the American Jobs Creation Act in 2004. We repatriated \$1.3 billion in offshore earnings to help fund this facility that we're building here in the United States.

The critical factor in the decision to build this facility in Richardson was really the climate for research and innovation. We've got about 180 very, very smart technologists and scientists that work in our company on advanced silicon process technology. And if we're going to attract those kinds of people to our location, we need to have, in close proximity, excellent research and development fa-

cilities. And the factor that really turned this deal for us and caused us to build this facility in Richardson was the commitment by the State of Texas to put \$300 million into the Engineering School at the University of Texas at Dallas. And this isn't to do contract research for Texas Instruments; this is to invest in basic facilities, to acquire top faculty, and to fund graduate students to do long-term basic research in silicon process and other advanced technologies that are important to our industry. If they hadn't have done it, we hadn't have come here, we wouldn't have built this facility here, and we need the Federal Government to continue to fund research that these faculty members will be doing, and that other faculty members will be doing in related areas at universities around the country.

You know, the Federal Government's role in basic research has always been critical. Jack Kilby invented the integrated circuit at TI in 1958, and it was support from NASA and the Department of Defense that really created the research environment for the semiconductor industry to grow and thrive in this country. Today, it's a \$215 billion industry. It employs over 225,000 Americans. And, you know, 30–40 years ago, nobody ever believed the semiconductor industry would contribute anything to the U.S. economy.

Kilby actually holds patents on the electronic handheld calculator, as well as the basic patents on semiconductors. And he did that to prove there would be commercial viability to semiconductor technology. But the Federal Government knew it before anybody else knew it.

Another example of how investments in basic research translate directly into jobs is in technology known as "digital light processing," and I've got a DLP chip here. There are about 1 million individual tiltable mirrors on this single piece of silicon. Each one of these 1 million mirrors can flutter up to 5,000 times a second. And this is the core engine in advanced display technologies that you're seeing in digital cinema, digital TV, and office and conference-room projectors. This arose out of a basic research program in the Department of Defense, 25–30 years ago, to improve cockpit displays. And today it's a technology that employs 1,000 people in our operations in Dallas, Texas, who work in our DLP division. But it's another example of how investments in basic research translates directly into jobs for our country.

The chip industry invests about 13—or about 15 percent of our revenue into basic research every year. TI will spend \$2 billion this year on basic research—or, excuse me, on research and development, but a lot of it is in the development side of the house. Our products have very, very short life cycles, sometimes mentioned in months. And many of our key business—the high-performance analog business, for example, 50 percent of our product portfolio was invented less than 3 years ago.

So, you know, we've got to invest in the short-term and bring products to market as quickly as we can. And that means we're going to have to rely, longer-term, on universities to do the long-term basic research that's important for the health of the semiconductor industry.

This is critically important at this time in our industry's history, because probably in about 10 to 15 years, we're going to reach the

end of how many circuits we can pack on a single piece of silicon using current manufacturing processes. So, we've got to get about the business of inventing the breakthrough innovations in advanced research on microelectronics and things like nanoelectronics if we're going to remain competitive in this global industry. And, I'll tell you, universities in India and China and elsewhere are making the investments in nanoelectronics and other areas in order to try to pre-empt this very, very important field in the future.

So, what's been proposed, in terms of the NSF funding, funding through DARPA, funding through NIST, funding through the Competitiveness Initiative that the Administration's proposed, we view as very, very important and fundamental to the future competitiveness of our company and our industry.

Thank you for the opportunity.

[The prepared statement of Mr. Ritter follows:]

PREPARED STATEMENT OF PHILIP J. RITTER, SENIOR VICE PRESIDENT,
PUBLIC AFFAIRS, TEXAS INSTRUMENTS

Chairman Ensign, Ranking Member Kerry, members of the Committee, thank you for the opportunity to testify today on the importance of basic research to U.S. competitiveness.

Texas Instruments is a company with a 75-year history of innovation. While our products have changed many times over the years, we have always fundamentally been a company of engineers and scientists. We have always looked to the future by investing in R&D. Based in Dallas, TI has become the world's third largest semiconductor company.

American competitiveness is the highest public policy priority for TI. We view increased investments in basic research, along with math/science education and access to a skilled workforce, as the three critical components to the future competitiveness of both our company and our Nation.

Research and Investment

Let me provide an example of the power of investment in research on economic development. Three years ago, Texas Instruments had a \$3 billion decision to make about where to locate our new semiconductor manufacturing facility. We looked at sites around the world, and many countries offered attractive incentives.

This year, we will complete construction on our new state-of-the-art facility—in Richardson, Texas, a Dallas suburb. When operational, it will produce the most advanced semiconductors in the world, support over 1,000 direct jobs, and bring thousands of indirect jobs to the Dallas area. An economic impact study estimated the investment would generate \$13.2 billion in expenditures, \$7 billion in gross product, and support 82,404 permanent jobs in the Dallas/Ft. Worth area.¹ The total cost of the construction is \$321 million. Of that amount, 25 percent was spent with minority-owned businesses and more than 10 percent with women-owned businesses. This was an aggressive goal that we believe had never been matched in the Dallas area.

The new facility has environmental and energy conservation innovations, with anticipated 20 percent energy reduction, 35 percent less water usage, and 50 percent emissions reduction. For the facility, TI received the 2005 Summit Award for Environmental Excellence from the *Leadership in Energy and Environmental Design* program of the U.S. Green Building Council.

Research was *the* critical decision factor for making our investment in Richardson. First, access to our R&D staff based in the Dallas area drives better time-to-market. Second was a commitment by the state to invest \$300 million at the University of Texas at Dallas, to further develop research and engineering capacity and improve the innovation ecosystem of North Texas. The investment at UTD will enhance basic research capabilities in close proximity to several TI manufacturing facilities.

Co-locating research with manufacturing is critical in the semiconductor industry, as it creates an infrastructure that allows discoveries to go from "lab to fab" efficiently. Corporate R&D projects are frequently done in the same facility as volume

¹The Perryman Group. *Economic and Fiscal Impact of Texas Instruments 300mm Wafer Facility and Collateral Investment at UT Dallas*, June 2003.

manufacturing, to ensure smooth transition to the new technology with maximum yield. Often, new tools introduced in the R&D process become part of full-scale manufacturing.

TI invests \$2 billion annually, or 15 percent of revenue in R&D. Most of this spending is on the nearer-term “development” phase to ensure introduction of new products in an industry with short product cycles. In our high-performance analog division alone, we introduced 400 new products in 2004, and 50 percent of that division’s revenue was from products introduced within the past few years.

Leading-edge semiconductor companies are on a two-year cycle in reaching the next “technology node,” which is characterized by smaller and smaller critical dimensions of the components on a chip. For example, the minimum dimensions of individual transistors² are currently less than 50 nanometers.³ This is an outstanding example of nanotechnology in volume production today.

Basic Research Critical to Semiconductor Industry

In 1958, when Jack Kilby invented the integrated circuit at TI, many were skeptical about his discovery. NASA and the Defense Department were among his first supporters in the late 1950s, and Federal support was critical to developing the manufacturing technologies in the mid 1960s and 1970s. Today, the worldwide semiconductor industry posts annual sales of \$213 billion, with U.S. companies capturing about half of the market. The semiconductor industry employs a workforce of 225,000 in the U.S. Semiconductors have revolutionized the way we live, with computers, cell phones, broadband, television, medical imaging, and global positioning systems.

Another more recent example is Texas Instruments’ Digital Light Processing (DLP) technology. DLP is used in televisions, business projectors, and cinemas. The digital mirror device technology that underlies DLP was originally developed as part of the High-Definition Display Systems program at DARPA. Initial research started in the late 1970s as part of an effort to improve aircraft cockpit displays. DLP technology now employs over 1,000 TI’ers in Dallas.

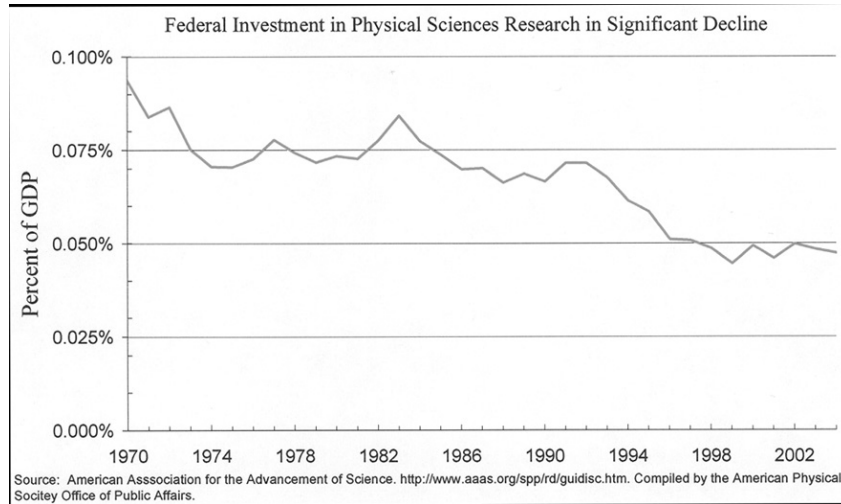
Overall, the U.S. chip industry invests 15 percent of revenue in R&D, one of the highest of any industry. However, given short product cycles, most funds are for relatively near-term development activity. For the majority of longer-term basic research, TI and other companies in the industry depend upon activities at universities and Federal labs.

The Federal Government is uniquely positioned to fund basic research. It historically has been a primary source of basic research funds for universities. The Federal Government plays an important role in supporting higher-risk, exploratory research where the economic benefits may not be realized for decades.

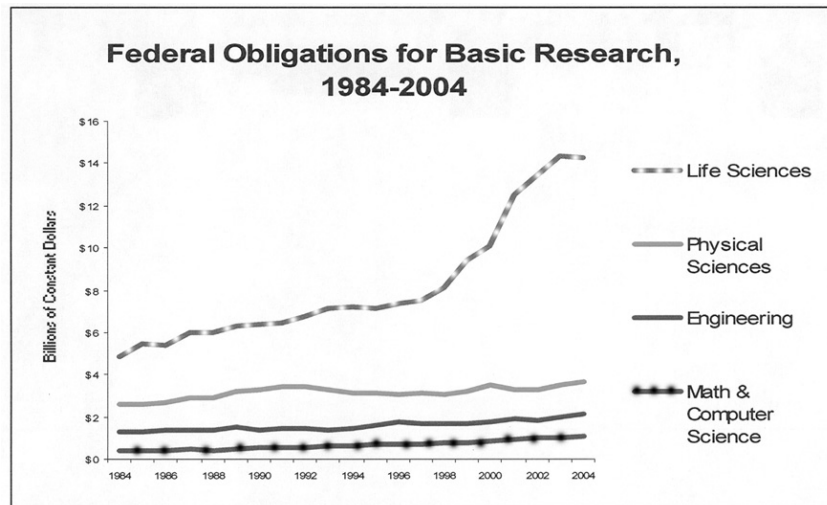
Yet, Federal investment in basic research has not kept pace in key areas such as engineering and physical sciences, whether for semiconductor related research or other areas of inquiry. It has been essentially flat for three decades. As a percentage of GDP, it has declined.

²A transistor is a component device that opens or closes a circuit.

³A nanometer is one-billionth of a meter. A human hair is roughly 50,000 nanometers wide.



While investment in the life sciences has grown exponentially, Federal resources in the physical sciences, engineering, math, and computer science have been stagnant. These neglected areas must be revitalized, at least at the levels proposed in the Administration's American Competitiveness Initiative.



Source: American Association for the Advancement of Science

There has also been a portfolio shift toward development activities, often at the expense of basic research. At the Department of Defense, basic research as a percentage of the total science and technology portfolio declined steadily from 1994 to 2004, to 11 percent.⁴

For the past forty years the chip industry has been delivering on Moore's Law, which states that every eighteen to twenty-four months the component content of a semiconductor chip will double. This means faster, more powerful and less expensive semiconductors. The Bureau of Economic Affairs estimated that Federal, state, and local governments saved a cumulative \$181 billion in computing price declines from 1995-2004.⁵

⁴ American Association for the Advancement of Science. Trends in DOD S&T, February 2005.

⁵ Bureau of Economic Affairs www.bea.gov/nea/dn/comp-gdp.xls.

But, to continue to deliver on Moore's Law, significant research hurdles must be overcome. The chip industry has mapped out the technical challenges it faces and the research needed to adhere to Moore's Law. Each year, the industry brings together 1,000 technical experts and updates the International Technology Roadmap for Semiconductors (ITRS). The ITRS identifies several hundred technical challenge areas that collectively comprise a "red brick wall"—in other words, problems for which there is no known manufacturable solution.

Collaborative research with outcomes expected in three to 8 years requires industry to pool its resources and partner with government. Longer-term research—8–15 years out—involves government-sponsored university research through the National Science Foundation, the Department of Defense, the National Institute for Standards and Technology and others to undertake the most fundamental research that will result in completely new technologies in the coming decades.

Industry experts agree that a replacement technology for the current 30-year old semiconductor process,⁶ which is reaching its physical limits, needs to be discovered and manufactured by 2020, to continue the historical trends of performance enhancements, size reductions, power conservation, and cost savings. Seminal research papers usually appear 12–15 years before commercialization, in other words *within the next few years*.

Key Agency Partnerships: Defense, NSF, NIST

The Department of Defense has historically been a funder of basic research in the physical sciences. However, in constant dollar terms, the level of basic research (6.1 account) at DOD was the same in 2004 as it was in 1984.⁷

The Focus Center Research Program is a partnership between the Defense Department and the semiconductor industry to fund university research at 33 institutions nationwide. All funding goes directly to universities, and funds research centered on the key technical challenges to extending the life of the current chip-making process and transition to the next technology. Federal funds are leveraged through an industry match, which is very rare for a basic research program. This is an excellent example of the type of activity the Defense Department can support with the basic research account. DARPA has been a great supporter of the program, providing both funding and expertise. Yet unfortunately, the Defense Research and Engineering request for the program has been at zero the past few years, requiring Congressional additions for the program to be fully funded.

The National Science Foundation is also critical to funding basic university research in the physical sciences and engineering. The Nanoelectronics Research Initiative (NRI) is a cooperative effort co-funded by NSF and the semiconductor industry to support university research to find the next generation of semiconductor technology by 2020.

Other countries are investing heavily in the nanoelectronics research area and could surpass U.S. discoveries in this area. If the U.S. does not discover and capture the new technology first, the U.S. semiconductor industry will be at a global competitive disadvantage. The NRI partnership will be key to this effort, and is an excellent example of how industry and the NSF can work together.

The National Institute for Standards and Technology (NIST) has ongoing activities relevant to the industry in semiconductor/electronics metrology (measurement), nanomanufacturing, and quantum information science.

Research and Workforce

Finally, basic research is important in terms of developing a workforce skilled in science and engineering. Many of the funds provide stipends for graduate students to conduct research in these fields, both during the course of their education as well as post-doctoral opportunities. It has been well-documented that students follow the money. Basic research in this capacity contributes to building the pipeline of students with advanced degrees in science, technology, engineering, and math fields. In turn, this builds a skilled U.S. workforce for our businesses.

Foreign nationals represent a large percentage of graduates from U.S. universities in science and engineering fields. In 2005, 55 percent of the Masters and 67 percent of the Ph.D. graduates in electrical engineering from U.S. universities were foreign nationals. Electrical engineers are in high demand, with an unemployment rate of only 1.7 percent. Unfortunately, current policies and long wait times for permanent resident status are a disincentive for these degree holders to stay in the U.S. and contribute to our economy. Most of these graduates have participated in important basic research at universities. Companies like Texas Instruments need to be able

⁶Complementary Metal Oxide Semiconductor (CMOS).

⁷American Association for Advancement of Science. *Trends in Basic Research*, March 2005.

to access all talent graduating from U.S. universities, regardless of nationality. Employing these individuals in the U.S. private-sector also assists the Nation in capturing returns on basic research investment.

Role of States

State governments are also critical in supporting public research universities from a budget perspective. In addition, states play an important role in facilitating commercialization from universities to industry. For example, Texas created a \$200 million Emerging Technology Fund. The fund has three goals: invest in public-private endeavors around emerging scientific or technology fields tied to competitiveness; match Federal and other sponsored investment in science; and attract and enhance research superiority in Texas. Several other states have similar mechanisms.

Last year, the President's Council of Advisors on Science and Technology issued a five-year assessment report on the National Nanotechnology Initiative. One of the recommendations was to increase Federal cooperation with the states, especially by leveraging state research investments. Further, the report recognized the important role of states in commercializing nanotechnology research results.

Conclusion

The American Competitiveness Initiative and 2007 budget requests on NSF, NIST, and DOE Office of Science will be critical to reversing the flat to downward trend in basic research in the physical sciences and engineering. The FY 2007 incremental increase is \$1.05 billion, which in the context of the overall Federal budget is relatively small. These increase requests are an investment in our country's future economic competitiveness, and should not be viewed as spending.

The technical challenges faced in the semiconductor industry provide just one example of the importance of basic research. The programs outlined in this testimony illustrate how the industry, Federal Government, and the states can work together to find research-based solutions that enhance our Nation's competitiveness.

Finally, the role of university research in TI's decision on where to build its new facility demonstrates how investment in research can be a powerful economic development tool.

Thank you for the opportunity to testify today. TI appreciates the Committee's interest in basic research and its role in U.S. economic growth. We look forward to continuing to work closely with you on the broader competitiveness agenda.

Senator ENSIGN. Thank you.

Dr. Drobot? You can just pull that microphone to you.

STATEMENT OF DR. ADAM DROBOT, CHIEF TECHNOLOGY OFFICER, TELCORDIA TECHNOLOGIES, INCORPORATED; CHAIRMAN, COMMUNICATIONS RESEARCH DIVISION, TELECOMMUNICATIONS INDUSTRY ASSOCIATION

Dr. DROBOT. Thank you, Chairman Ensign and members of the Committee. I am appearing today as the Chief Technology Officer of Telcordia, and also as the Chairman of the Telecommunications Research Division. And we are very grateful for the opportunity to appear before you today, and such a distinguished panel of witnesses, to discuss the importance of basic research to United States competitiveness.

If you look at the industry that I'm representing today, it's roughly 3.5 percent of our GDP. It plays a fundamental role that really touches all other industries. It impacts the productivity of our economy in very fundamental ways. And it's really the underpinning of law enforcement, emergency response, and a lot of things that go on in the Department of Defense.

One of the things that I'd like to convey is the fact that, as a scientist, we learned something called the Law of Continuity, "You don't put something in the hopper on the front end, nothing comes out the back." When it comes to technology, it's basic research, followed by transitional activity, followed by development. Having

that healthy front end of basic research is what makes the goods come out the other end of the pipe.

And when we look at what has happened over the last two decades in our own industry, the technologies in communications and services have not only benefited the United States, they've really led to rising standards of living around the world.

If we were to take a look at the critical elements of our infrastructure, telecommunications is a fundamental backbone, and the flow of new ideas from basic research to transitional activity to the development of the key next-generation services really requires that investment be made in the front end.

We believe that the advances that can be expected in the future can be summarized very simply by, "You ain't seen nothing yet." OK? If you look at the last 25 years, the explosive growth of the Internet, the use of computers in business, driving commerce around the world, the convenience of mobile cell phones, information services, how they impact how we spend our time, interact with our fellow citizens, you know, all of those things have been impacted by the way communications has gone over the last two decades.

The same is true of our national defense posture. If you look at the roadmap for that, as captured in Vision 2020, situational awareness, precision strike, dominant maneuver, focused logistics, all of those rely fundamentally on advances in communications.

It is vital, as a consequence, for the United States to maintain leadership in these areas and to be competitive in the future of this critical industry. And to steal the words from Vannevar Bush, "For the health, general welfare, and defense of our population." I think those wise words, said in the 1940s, apply as much today as they did back then.

Please let me turn to the situation as we see it today. Federal spending in our field, in communications research, as a percentage of the total spent on information technology has, in fact, gone down over the last 5 years. This is in the face of significant growing public investment in other geographies. If you were to look at examples in Europe, from the Framework Programmes, the national programs with the tiger economies in the Far East, China, these programs are accompanied by coordinated transitional activities where, in native markets, technologies are first deployed, with an aim to, in fact, dominate world exports in those technologies to other geographies.

If I were to look at specific examples, there is a new standard called WiMax. The first deployment of that on a national scale will be done in Korea by an initiative called WiBro. It's mobile services at 10 megabits per second, developed—delivered to a handheld device.

If I were to take a look at third-generation systems, the Internet protocol multimedia subsystems for all IP-based communications, those are first going to be developed and deployed in other geographies. While the United States is the single largest market for communications, and has a very robust economy, we now rank 16th in the penetration of high-speed networks.

If I were to go down through this litany, I think the future investments through the Innovation Act, through the President's pro-

posals, are really critical, and the investments to be made in basic energy—in, I would say, basic research are really the cornerstone of what ought to be done in the future.

Let me quickly, sort of, jump to the end of my presentation. What we have done is attach a white paper to this testimony. The Research Division at TIA, that I represent, has membership from 40 CTOs of U.S. corporations. And what we have done is prioritized, I think, the agencies we believe ought to be the recipients of those funds. They are NIST, DOE, and the 6-month programs in the Defense Department. We have also prioritized the directions those investments should go in: security, broadband, the use of nanotechnology for telecommunications.

And if I could share with you a couple of examples, we believe that if those investments are made, there will be future devices that are just as exciting as what's happened the last quarter century, integrated devices that you can hold in your hand that do everything from communications, projection, viewing information, greater connectiveness—and all of those at incredible speeds. We hope the kind of investments that are made in interfaces, are simple enough that all citizens can easily use them.

Same is true, if I were to take a look at the amount of time we spend in automobiles and on the roads, reduction in the number of traffic accidents and deaths by a factor of two over the next decade or so—again, enabled by fundamental changes in the communication industry.

Growing problems in healthcare with an aging population. Again, communications can play an incredible role in that. The same is true of new economic systems.

What we hope is that the investments that are made here, will create the critical mass of citizens, of businessmen, and scientists who are familiar with technologies and can make the breakthroughs. We hope that those do not happen first in other geographies.

So, I'd like to thank you for the opportunity to appear before you today, and we hope that the critical needs of this industry, and, really, of all basic research in the United States, are met.

Thank you.

[The prepared statement of Dr. Drobot follows:]

PREPARED STATEMENT OF DR. ADAM DROBOT, CHIEF TECHNOLOGY OFFICER, TELCORDIA TECHNOLOGIES INCORPORATED; CHAIRMAN, COMMUNICATIONS RESEARCH DIVISION, TELECOMMUNICATIONS INDUSTRY ASSOCIATION

Thank you, Mr. Chairman, Ranking Member Kerry and members of the Committee. I am appearing today as the Chief Technology Officer of Telcordia Technologies Incorporated and as the Chairman of the Telecommunications Industry Association's Communications Research Division. Telcordia is grateful for the opportunity to appear before you today among such a distinguished panel of witnesses to discuss the importance of basic research to the United States' competitiveness.

Telecommunications, as an industry, represents about 3.5 percent of our Gross Domestic Product and plays a fundamental role that touches all other industries, impacts the productivity of our industries and our economy, and pivotally effects emergency response, law enforcement and national defense. Prior investments in basic and transitional research, and aggressive development of new communication technologies and services, have benefited the United States through significant gains in productivity and contributed to raising standards of living around the world. Today, communications represent a critical element of our infrastructure and form the backbone on which all industries and government depend. No industry

could function effectively today without communications. The flow of new ideas from basic research to transitional activity to development is the key to continuing the creation of the next generation of communication technologies and services.

The advances we can expect are as profound and far-reaching as what we have experienced over the last quarter century—the explosive growth of the Internet, computers connected by high-speed networks driving commerce around the world, the convenience of wireless mobility, and information services which are changing everything from how we spend our time to how we interact with our fellow citizens. The same is true of our national defense posture, where the four elements of Vision 2020, situational awareness, precision strike, dominant maneuver, and focused logistics, rely on advanced communications and networks. It is vital for the United States to maintain the leadership and future competitiveness in this critical industry—for the health, general welfare and defense of our population.

Please let me turn to the situation today. The Federal spending on communications-focused basic research, as a percentage of total Federal information technology research and development in the United States, is declining—down 5 percentage points in the last 6 years. This is in the face of significant growing public investments in other geographies. Examples are: the Framework Programmes in the European Union; national programs in Korea, Taiwan, Hong Kong, Singapore and Japan conducted through national laboratories and economic development authorities; and growing investments in China targeted at all aspects of communications. These programs are further accompanied by coordinated transitional activities which forge academic, national laboratory, and local industry partnerships aimed at native deployment and eventual domination in international markets. An example would be the deployment of “WiBro” in Korea—this is high-speed Internet connectivity at speeds greater than 10 megabits per second for ubiquitous fixed and mobile wireless services based on the WiMax standards. A by-product of the early stage investment in innovation that these geographies have made is the deployment of next-generation systems significantly ahead of the United States. These systems enable third generation (3G) and Internet protocol multi-media sub-system (IMS) services.

While the United States is still the single largest market for communications and has the most robust economy, we now rank 16th in the penetration of high-speed broadband, and we have not commercially brought 3G or IMS services to the consumer. As a consequence, it is more than likely that the next wave of services and technologies will be developed where test beds and deployment of infrastructure will support experimentation of new concepts and ideas and where the human capital is concentrated—locations where business executives, scientists and engineers are familiar with the technology. The experience from my own corporation confirms this. Telcordia, which traces its heritage to “Bell Labs” and which participated in the invention of much of modern communications, is the largest seller of operations support systems to the telecommunications industry. To maintain our edge, we are finding it a necessity to rely on growth in foreign markets and are facing increasing foreign competition, which is advantaged by public spending in the local markets and long-range government funding.

Speaking as the Chairman of the Telecommunications Industry Association’s Communication Research Division, our Division—made up of Chief Technology Officers and heads of research from 40 companies—is advocating that Federal funding for communications-specific, pre-competitive, basic research be increased beyond the 0.07 percent¹ of total Federal R&D that we have identified as targeted at communications in the current budget. The members of our Division believe that research is the foundation of the communications industry and the building block for future products and services. As an industry, we are not looking for a hand-out. To the contrary, we are asking that the Federal Government invest more of its research dollars in this critical area. This will benefit companies, universities and national laboratories in the long-run, and it will make our Nation stronger—economically and technologically. We are encouraged by the President’s American Competitiveness Initiative and support the doubling of budgets in the National Science Foundation (NSF), National Institute of Standards and Technology (NIST), and the Department of Energy’s (DOE) Office of Science. We would like to convey to you that developing leading-edge communications applications is complex, requiring, time, money, and long-term vision. Fierce competition and financial realities have made it difficult for U.S. industry to self-fund long-term, basic research, and because the U.S. Government is not devoting sufficient resources on long-term communications research, the U.S. position in this vital area is waning.

¹\$100 million out of a \$137.2 billion Federal research and development budget for FY 2007.

We include a copy of a white paper from the TIA Communications Research Division as part of the testimony. In it, we recommend that increased funding focused on communications basic research in NSF, NIST, and the Department of Defense (DOD) 6.1 will greatly benefit the Nation. We further recommend investing additional money in: Universal Broadband; Network Security; Interoperable Mobility; Telecommunications Research for Homeland Security; Networking Architectures; and Communications-Specific Nanotechnologies as priority areas.

I would like share some examples where the investments that we propose could impact the citizens of our great country:

- In everyday life—devices with much simpler interfaces, but at the same time, much more functionality with greater adoption in our society—Imagine a single device the size of your cell phone today, which is your PC, your camera, a projector, shows HDTV, plays music, is a portal to the internet—without a button in sight?
- Reduction in traffic accidents and deaths—sensors on a car that could alert you to hazardous conditions, such as black ice, another vehicle in your blind spot when you are about to change lanes, a deer in the roadway, a washout in the highway, and the communications system that can convey warnings about such hazards to traffic behind you.
- Healthcare for the elderly—a handheld device that your grandmother has, which could diagnose and warn about medical problems, call for a nurse or a doctor's intervention, or improve quality of life by fostering the ties with a grandchild three time zones away through effortless, high-quality communications.
- New commercial systems—a slim and light portable device to securely purchase, receive, redeem, and store concert tickets, airline boarding passes, subway tickets, and conduct financial transactions from anywhere—without printing a thing?

I would like to close by saying that U.S. industry is unable to fully self-fund the research necessary to discover and exploit long-term, ground-breaking advances so critical to the health and competitiveness of the Nation. The history of the telecommunications industry has left us with weak public mechanisms for funding pre-competitive research in communications, paradoxically, because so much of the research was initially done in a dominant institution—"Bell Labs." While that institution left an incredible legacy of successful inventions which has paid off well for our Nation—the mechanisms of funding on which it depended no longer exists. New partnerships between industry, government and universities are needed to meet tomorrow's challenges and to maintain the competitive position of the United States in the communications industry.

Thank you once again for the opportunity to appear before you today.

INVESTING IN COMMUNICATIONS FOR TOMORROW'S INNOVATIONS: THE CASE FOR INCREASED COMMUNICATIONS RESEARCH FUNDING

Background

Research is the backbone of the communications industry, a critical national resource. It is the building block for the future development of advanced telecommunications products and services. In recent years, the need for federally-funded communications research has dramatically increased. As a result of the communications market crash of 2000, intense market competition and a focus on low price points keeping profit margins at a minimum, companies remain focused on survival. This has translated into an era of deep cost-cutting and lean workforces, as well as a focus on product development and incremental research, rather than innovating for the future and seeding technology development. While the United States has been and continues to be regarded as a leader internationally in technology research, the innovation of recent years *cannot be taken for granted*.

Why Federally-Funded Communications Research Is Necessary

The nature of communications industry investment is long-term, capital-intensive and generally, non-cyclical. At the same time, the process of conducting communications research is extremely complex—involving time, money and foresight that must be sustained for a decade or more to yield the full fruits of investment.¹ Because

¹ See PITAC presentation at <http://www.itrd.gov/pitac/meetings/2004/20041104/compSci.pdf>.

of the tremendous infrastructure requirements associated with the deployment of communications networks, a great deal of time, money and vision is needed to advance challenging, high-risk, enabling technologies that could provide broad-based economic and societal benefits for the U.S.² This is precisely why, with constantly diminishing corporate research funds available, the Federal Government's budget for research has become an increasingly important source of funding for U.S. communications research.

Advances in communications dramatically transform the way in which people live, work, learn, communicate and conduct business, and long-term research is essential to ensure that these transformations serve human needs, are productive for society and sustainable over the long-term. Moreover, long-term communications research has significant positive effects, in terms of technical and economic spillovers. Research is a key factor in enhancing innovative performance and productivity, as well as long-term economic growth. This is because communications is a supporting sector for the economy as a whole, affecting many specific industry sectors, such as distribution, retail, agriculture, financial services and machine building, among others. In fact, all sectors depend on and derive benefits from communications research. This is precisely why the Federal Government should be concerned about the poor state of funding for communications research and should more actively support the sector.

Research in this area is the principal source of fundamental advances in the digital technologies powering vital national defense, national security and homeland security capabilities. A strong, well-funded communications research program benefits innovation in vital infrastructure protection measures, such as increased information security, reliability and survivability of networks, as well as facilitates development of the technologies and tools used to detect and prevent terrorist attacks.³

Current State of Federal Communications Basic Research Funding in the U.S.

For years, when compared with other industries, communications basic research has not been well supported in the U.S. Government's Federal budget. In Fiscal Year 2007, the Federal Government budgeted a little more than \$3 billion⁴ across relevant agencies for networking and information technology research and development (NITRD). This is a minute fraction—*about 2 percent*—of the \$137.2 billion⁵ in total research and development funding requested for this fiscal year.

To further illustrate the lack of Federal focus on communications basic research, the total amount of Federal funding budgeted for *large scale networking (LSN) research*—the part of NITRD that includes communications and high-performance networking research and development in leading-edge technologies and services—*totaled about \$400 million⁶ in Fiscal Years 2006 and 2007*, or about *0.3 percent* of the Federal Government's total research and development budget. Given the fact that LSN includes more than just communications-focused basic research, and this figure includes both research AND development spending, as well as spending on infrastructure and applications, only a fraction of this number is actually spent on communications basic research, likely *no more than \$100 million*.

Moreover, between Fiscal Years 2002 and 2007, the percentage of U.S. Government research funding allocated to the large-scale networking program area *declined by 5 percentage points*, from 18 percent to 13 percent (see the chart⁷ below). All of these statistics suggest that the Federal Government views communications-sector basic research with decreasing importance to the economy and security of the United States, this despite the fact that communications is a critical infrastructure and it is the backbone for all information technologies. Communications are an indispensable part of every other industry, from automobile manufacturing to

² ATP Document on Investments in Telecom and Related Technology Fields, 2003.

³ See Networking and Information Technology Research and Development FY 2004 report.

⁴ See http://www.nitrd.gov/pubs/2007supplement/07%20Supp%20Sections/07Supp_FINAL-AgencyNITRDBudgets.pdf.

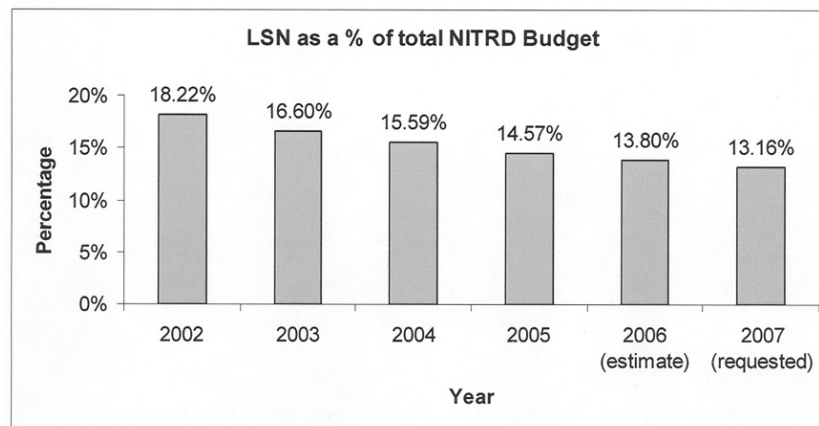
⁵ See <http://www.ostp.gov/html/budget/2007/2007FactSheet.pdf>.

⁶ For the first time, the NITRD LSN budget for FY 2006 and FY 2007 includes research statistics from the OSD budget. The OSD budget includes funding from the DOD Service research organizations (Air Force, Army and Navy), as well as DOD's High Performance Computing Modernization Program Office. Once this line item is subtracted, the total amount of funding allocated for the LSN Program Area in FY 2006 is \$252.1 million, and FY 2007 is \$273.8 million. No similar statistics are publicly available pre-FY 2006, and the addition of these statistics into Federal reporting charts makes year-on-year comparisons nearly impossible to make.

⁷ See http://www.nitrd.gov/pubs/2007supplement/07%20Supp%20Sections/07Supp_FINAL-AgencyNITRDBudgets.pdf.

healthcare to financial services and more. No industry today could survive without communications technologies and services.

The following chart depicts LSN as a percentage of the total NITRD budget during the past six Fiscal Years.



U.S. Communications Research Falling Behind Other Countries

Communications is a highly competitive, global industry. With relatively little Federal and industry money going toward long-term, high-risk communications research, the leadership position of the United States in this vital area is waning, threatening our country with potential innovation declines. Decreasing emphasis domestically, both in terms of political support and dollars, on the importance of funding research in this field is strengthening the growth of research funding and related institutions overseas, as other countries seize an opportunity to outpace the U.S. in this important, strategic field, and companies find high-level support from other governments. This creates an incentive for companies to move research facilities to other countries where funding and support exist.

For example, Europe is in a competitive race with the U.S. and Asia for a leadership position in technology, especially technology that will impact global markets. In the European Union's (EU) 6th Framework Programme,⁸ 3.98 billion euros of funding has been prioritized for information society technologies (IST) research, making it the main source of EU funding for IST research projects.⁹ This is part of the EU's overall goal to increase research and development expenditures to 3 percent of GDP by 2010, and this also makes IST research the largest funding priority in the entire EU research program. According to the European Commission, "Europe can lead the world if it can develop a common vision embracing researchers, industrialists, governments and societies across Europe."¹⁰

The EU also is currently developing its 7th Framework Programme (FP7).¹¹ Entitled "ManuFUTURE Vision for 2020," the EU's new Framework focuses on innovation in underlying technologies that will enable more efficient manufacturing. FP7 aims to move the EU from an economy of quantity to one of quality by using digital methods to integrate new technologies into the design and operation of manufacturing processes. The EU's goal is to optimize resources and transfer them to all areas where they can be employed, thereby remaining competitive in a global marketplace. Funding for IST research in the 7th Framework Programme has increased more than three-fold over the 6th Framework Programme, to 12.7 billion euros.¹²

China has developed a five-year plan for the 2001–2005 period, which purports that the communications industry will be the leading industry among all other industries in its national economy, and the country announced plans to shift resources toward achieving this goal.¹³ In fact, between 1996–2002, China's science and technology research and development funding, as a share of GDP, doubled from 0.6 per-

⁸ 2002–2006.

⁹ See http://europa.eu.int/information_society/research/index_en.htm.

¹⁰ See http://europa.eu.int/information_society/research/index_en.htm.

¹¹ See http://europa.eu.int/comm/research/future/index_en.cfm.

¹² See <http://www.cordis.lu/fp7/breakdown.htm>.

¹³ See summary of China's tenth five-year plan.

cent to 1.2 percent.¹⁴ According to the OECD, its total R&D investments lag only those of Japan and the United States in absolute terms.

The United Kingdom (UK) has set a target to increase its share of publicly-funded science and technology research and development from 1.9 percent to 2.5 percent of GDP by 2014. The country's *Science and Innovation Investment Framework*¹⁵ proposes that the public science budget increase 5.8 percent annually, in real terms, from 2004–2005 and 2007–2008.¹⁶

In December of 2005, the Academy of Finland and the National Technology Agency Tekes launched a new research funding program. This program aims to strengthen science and technology research by attracting top foreign personnel to conduct research for a fixed time-period in Finland. Researchers will focus on basic research, science and researcher training.¹⁷ Tekes, the main Finnish research funding body, allocated 409 million euros to research programs in 2004, with 122 million Euros going to information and communication technology research.¹⁸

Japan raised the total amount of government research and development spending by nearly 24 trillion yen (about \$233 billion) between FY 2001 and FY 2005. And, the Korean government set a target to double national research and development spending between 2001 and 2007.¹⁹

An increasing number of OECD governments are offering special fiscal incentives to businesses to increase spending on research and development, largely because R&D and innovation are considered keys to productivity and growth performance. For example, the countries of Japan, Korea, Portugal and Spain all offer greater tax incentives than the U.S., at rates of 45–50 percent, on incremental increases in science and technology research and development investment.²⁰ Additionally, unlike in the U.S., many countries—including Australia, Austria, Belgium, Denmark, Hungary, and the UK—offer generous tax allowances of greater than 100 percent for research and technology development.

These are just a few examples of how other countries are investing the time, money and intellectual capital to create attractive environments for science and technology research. The United States cannot afford to ignore the fact that U.S. industry needs Federal Government support in order to remain competitive for the long-term.

TIA's Solution

With this background, TIA's Communications Research Division has identified four mechanisms to address the funding problem and six technical areas where we would like to see Federal funding for communications research directed. Further information about these items is attached. In addition, we believe policymakers should reflect on these issues as discussion occurs regarding a rewrite of the 1996 Telecommunications Act.

TIA PRIORITY AREAS FOR FEDERALLY-FUNDED COMMUNICATIONS RESEARCH

Mechanisms To Address the Funding Problem

1. Prioritize communications research funding within Department of Defense (DOD) 6.1 Basic Research Programs.

a. In the 1990s, the Department of Defense and the Defense Advanced Research Projects Agency (DARPA) began to rely heavily on dual-use and industry research funding. Thus, DOD funding became unavailable for technologies that were commercially available. As a result, DOD restricted its research funding to military-unique needs, which at the time was acceptable because private-sector-led research was driving high-end research.

b. With the communications downturn, however, the commercial sector has ceased to be the major driver of high-end, long-term research. As a result, DOD—and DARPA—need to increase their focus on and investment in dual-use technologies.

2. Prioritize communications research funding within the National Institute of Standards and Technology (NIST).

¹⁴ *OECD Science, Technology and Industry Outlook*, 2004, p.18.

¹⁵ See http://www.hm-treasury.gov.uk/spending_review/spend_sr04/associated_documents/spending_sr04_science.cfm.

¹⁶ *OECD Science, Technology and Industry Outlook*, 2004, p.56.

¹⁷ See http://www.tekes.fi/eng/news/uutis_tiedot.asp?id=4593.

¹⁸ See <http://www.tekes.fi/eng/tekes/rd/statistic04.html>.

¹⁹ *OECD Science, Technology and Industry Outlook*, 2004, p.57.

²⁰ *OECD Science, Technology and Industry Outlook*, 2004, p.66.

- a. Miniaturization of electronic components in communications devices continues, resulting in faster, more powerful and more reliable products. Yet, the continued shrinking of component parts, at the nanoscale, is hindered by metrology and manufacturing challenges. NIST programs address some of these key issues and should be adequately funded.
 - b. Additionally, we support the continuation of the National Information Assurance Partnership (NIAP), a collaboration between NIST and the National Security Agency. The long-term goal of NIAP is to help increase the level of trust consumers have in their information systems and networks through the use of cost-effective security testing, evaluation, and validation programs.
3. Prioritize communications research funding within National Science Foundation (NSF) Research programs.
- a. Federal funding for physical sciences research, the foundation of our Nation's economic competitiveness, has dramatically decreased. Technological advances driving the economy require the reversal of this trend.
 - b. The National Science Foundation Authorization Act of 2002 called for doubling the NSF budget over 6 years; fulfillment of that goal is lagging.
 - c. In conjunction with increasing NSF's budget, we advocate for the creation of an NSF Communications Technology Research (CTR) program, similar to the Information Technology Research (ITR) program that recently concluded. Such a program would greatly benefit the communications sector by creating opportunities at the frontiers of communications research and education.
4. Establish a National Technology Council, whose charter would be to define and guide strategic areas in communications that require further research critical to the future growth of the U.S. economy. Such a Council should include representation from different sectors, such as government, academia and industry.
- a. To utilize scarce financial resources effectively, representatives from government, academia and industry should be sought to establish long-term priorities. Additional research would help identify the technologies likely to be most relevant to U.S. economic growth and competitiveness.
 - b. This Council should be modeled after the European Union's 6th Framework Programme initiative, wherein the Council receives proposals from industry consortia regarding specific areas of focused research and development and has available substantial funding from the government to help fund those proposals.
 - c. This Council should also borrow from the United States Alliance for Technology and Engineering for Automotive Manufacturing (U.S. A-TEAM), a partnership created between the U.S. Department of Commerce's Technology Administration (TA) [consisting of the Office of Technology Policy (OTP), the National Institute of Standards and Technology (NIST), and the National Technical Information Service (NTIS)] and the United States Council for Automotive Research (USCAR). U.S. A-TEAM brings together engineers from the government and industry bodies that are parties to the agreement to facilitate technological research and technology policy analysis focused on improving the manufacturing competitiveness of the U.S. automotive industry.
 - d. The Council, in cooperation with industry, would determine the priority of the specific research initiatives of national concern.

Technical Areas Where Research Is Needed

1. Universal Broadband—Affordable broadband access and connectivity, using all available media (copper, coax, fiber, spectrum, etc.), carrying all services (voice, data, video) to all customers everywhere (urban, suburban, rural, mobile) in order to enable a greatly upgraded "superhighway."
 - a. Broadband Internet access is critical to support technology convergence and advanced communications. A forward-looking U.S. Government should support universal access for broadband Internet, as well as policies that promote widespread connectivity. Infrastructure upgrades create increasing returns to our economy and encourage the development of businesses, entertainment, education, and e-government solutions and capabilities.
 - b. Additional *federally-funded* research in this field is needed, particularly because special technologies will be needed for rural access, and corporate and venture capital financing for research has dropped significantly over the last several years. Extremely significant cost reductions are necessary in order to meet the technology needs of rural areas. Additionally, the provision of

broadband access in rural areas is costly due to challenges associated with terrain, low population density, etc.

2. Security—New authentication, encryption and monitoring capabilities for all public broadband networks to protect communications assets from attack.

a. The U.S. is a post-industrial information society, and as such, its cyber-infrastructure is vulnerable to attack.

b. Continued research is needed to prevent systemic attacks to infrastructure and may provide an opportunity for university-based “centers of excellence.”

3. Interoperable Mobility—The ability to access commercial mobile services and emergency services over any mobile network from any mobile instrument.

a. Interoperable mobility enables public safety and law enforcement officials to use the various public safety and cellular mobile networks while avoiding the necessity of carrying multiple mobile devices. It also promotes coordinated communications between various public service agencies and allows higher-priority use of scarce spectrum resources for emergency use.

b. Federally-funded research is necessary because the emergency services market is critical for the common good. Also, bringing commercial technologies and emergency services technologies closer together will result in lower costs and more advanced features for critical emergency services.

4. Communications Research for Homeland Security, including interoperability, security, survivability and encryption.

a. Homeland Security is a superset of several other listed visions. Security technologies can help protect public networks and other public infrastructure from malicious attacks. A large amount of economic activity today depends on the continued availability of public broadband networks and infrastructure. Successful attacks can significantly slow down national economic activity and can have other disastrous consequences (*e.g.*, in case of identity theft).

b. Research is needed in all areas (interoperability, security, survivability and encryption) because the needs of first responders and critical infrastructure protection far exceed the needs of “typical” commercial applications. Further research also is needed because new worms and viruses constantly are being invented, and new techniques are needed to prevent attacks before there is significant resulting damage.

c. The country needs a broad program to address our vulnerabilities and ensure the integrity of first responders’ systems. The government should support these “extreme case” applications, since they are unlikely to be sufficiently developed in normal commercial systems.

5. Nanotechnology.

a. Many of the advances in communications have been driven by fundamental scientific discoveries of materials at the nanoscale level.

b. Examples of important research areas include: sensors, displays, power systems, radio frequency and nanomicrophones.

c. Advances will reduce cost, increase mobility, decrease power consumption, and improve healthcare, homeland security and public safety.

6. Networking Architectures.

a. Advanced networking research on hardware and software for secure and reliable communications and tools that provide the communication, analysis and sharing of very large amounts of information will accelerate discovery and enable new technological advances.

Senator ENSIGN. Thank you.

We’ve been holding a series of hearings—those of you who are paying attention—on education, regulation, various other ways that our global competitiveness is affected. And even what affects how capital is going to be available to firms? You know, what kinds of things do we need to do up here to make that capital available that the private-sector is willing to put at risk to make us stay on that competitive edge? So, we’ve been taking a holistic approach to this whole competitiveness issue. And, obviously, the purpose of today’s

hearing is to discuss the importance of basic research and the dollars applied to that research. There's no question that broadband and our bill for video franchising and trying to encourage the investment in our broadband infrastructure and our high-speed infrastructure is critical to this whole aspect of remaining competitive. But that is another topic for another day.

I would like to explore just a little bit, though, and maybe start with you, Dr. Drobot, because of the industry that you are in. You know, Bell Labs was a preeminent research institution when AT&T had a state-sanctioned monopoly. But, no longer—we don't see nearly the investment in basic research—they used to do even basic research with some of their applied research. Why the change today, compared to what it was some time ago, as far as basic research is concerned, from the private-sector?

Dr. DROBOT. I think it's a, you know, fantastic question. OK? Let me—and I have a little bit of this covered in the testimony. You know, fundamentally, in 1984, almost all research in communications was done by Bell Labs. There was a funding mechanism for doing this, and that was a small tax on every telephone call. And if you look at the style of the research that was done, there was a large basic component. If you look at the laser, you look at the transistor, you look at a lot of the fundamentals, OK, they came out of Bell Labs. I think they enriched the Nation, they enriched the world.

With the dissolution of AT&T, what you find is that that kind of funding mechanism disappeared. I represent a company that came off the Bell Labs stem. It was called Bellcore. It supported the Regional Bell Operating Companies. Roughly a third of Bell Labs was in it. In today's world, with the pressures, just as at TI, we cannot afford to fund basic research. Everything gets turned out on 6-month/12-month cycles. That's not basic research. The pressure is to produce more of those kind of goods. And so, basically, the mechanisms of collecting enough funds that are actually tied to needs and requirements is broken, as a mechanism.

Senator ENSIGN. OK. I need to attend to another matter briefly. I was hoping that one of the other Senators would be able to take over in my absence. But, we'll take a short recess, and then we'll reconvene.

[Recess.]

Senator ENSIGN. The next place I want to explore is the global nature of competitiveness. A couple of you mentioned the rest of the world in your testimony. "Competitiveness" means that we are competing against somebody. And the rest of the world is starting to step up. We realize that. And I think that it is the exact, right observation that some have made that as the rest of the world improves, we have to worry about what we're doing. We have to worry about us getting better. But we also have to put that a little bit in context of what the rest of the world is doing. They are increasing the amount of money that they are spending on research and development, and they are certainly focusing more on education, graduating a lot more engineers and a lot more students with advanced degrees than we are here in the United States. And that is why a big part of our competitiveness, depends upon our education.

Maybe you could make some comments about the rest of the world. Europe is increasing investments in innovation. Asia is increasing investments in innovation. Some other places are increasingly focusing on innovation. But can you just put that in context with how much we're spending on innovation and related education, compared to the rest of the world?

Let's start with Dr. Knapp. You know, how much the United States invests as a percentage of GDP in basic research. But can you tell, as far as total dollars—what we're investing in research, compared to some of the other nations, Europe or Asia?

Dr. KNAPP. Mr. Chairman, I—we can certainly—well, I don't have that data right in front of me, in terms of comparing the percentage of GDP here in whole dollars.

Senator ENSIGN. You don't have to give me exact numbers, but—

Dr. KNAPP. Yes. I mean, our—

Senator ENSIGN.—from what I understand, we're still investing a lot more than the rest of the world.

Dr. KNAPP. Yes. And—but there does seem to be—and we have a lot of connections with China right now. We have a campus, actually, in Nanjing, China, which we've operated for more than 20 years now. And so, we're constantly in dialogue with people in technical fields there. And what seems to be the case is this kind of seamless—and I think this was mentioned by earlier witnesses—the seamless relation that is very carefully planned between what goes on in the schools, in feeding students and preparing the infrastructure and all the rest of it. And whatever the overall rate of expenditure is, there is a strategic and a kind of aggressive focus there that we've noticed.

There's an aspect to this that I mention in the written testimony, did not touch on in the oral testimony, that I think is—also needs to be brought into the picture, and that is that for many years we have benefited from foreign talent coming to this country in a very extraordinary way, and that has, of course, now been complicated because of the conditions created by the war on terrorism. And one of the things—we've been working very closely with the relevant Federal agencies on trying to get enough of a system arranged for immigration to make it possible for talented scientists and engineers to come to this country and to work here, and, if they are effective contributors, even to achieve permanent residence here. That's become more difficult now than it used to be. And it's—you know, I have statistics in the written testimony about the loss of access to graduate students and post-docs and young scientists.

Senator ENSIGN. We have that. And, actually, you mentioned Dr. Craig Barrett. He testified a few weeks back on the idea of attaching a visa or green card to advanced degrees. And we're looking into immigration reform, as you may have noticed in the papers.

[Laughter.]

Dr. KNAPP. Well, I—

Senator ENSIGN. We are actually looking at what the Committee has done and I don't know if you've looked at the Committee bill that came out—but we're looking at that. And if there are some additional things that need to be done. There is no question that our current system is crazy. I mean, we subsidize foreign students edu-

cation, then we say, "When you're done, you go back." I mean, that is just as stupid as anything that we have ever done. We've always been the brain drain for the rest of the world. And, I think that we should continue to be, because talented people come here and create jobs. And that has to be part of our overall strategy. And one of the great things—you know, I look back—and you think about Japan, back in the 1980s especially, and you heard some Americans saying, "Well, you know, we can't compete." You know, part of the beautiful thing about our system—and even when you look at India and China, part of the beauty of our system is that we have this entrepreneurial spirit that, due to the freedoms that we have, is unmatched anywhere in the world. And it is part of our economic system. It's just part of our system of government. It's part of everything here, and I think it will remain an advantage for the United States into the future. But we still have to watch what they are doing elsewhere around the world and look at the strategies that they are using, and not rest on our laurels. And that's part of what we need to focus on.

Dr. KNAPP. Sir, if I might comment on that—on that point, just to highlight what you've just said, I think it is absolutely the case that—our experience is that the kinds of education we provide in science and technology, because of that flexibility and that entrepreneurial spirit, remains a key advantage that the United States has over these other institutions in Asia and elsewhere. Right now, however, the other countries are aggressively going after the students who are not finding a comfortable reception—

Senator ENSIGN. Right.

Dr. KNAPP.—here. And that includes commonwealth countries that are English-speaking, and they have a systematic approach to that, which I think is cutting into what used to be a very powerful brain drain to the advantage of this country.

Senator ENSIGN. I agree.

Dr. Pietrafesa?

Dr. PIETRAFESA. Yes, I'll comment in several ways. One is that the ocean and atmospheric sciences are funded by several agencies principally, for example, the Office of Naval Research, which was actually the first funding agency for basic research in the United States. It preceded NSF, after the second World War. But ONR, along with the Department of Energy, funded not only basic research in the ocean and atmospheric sciences, but actually funded the development of new instrumentation and advanced new technologies. But both have significantly reduced funding for basic research. The Department of Energy has essentially gone out of the ocean and atmospheric sciences research funding business. So, that has put more pressure on the National Science Foundation and on NOAA.

Now, the National Science Foundation, I understand, had up to \$2 billion worth of unfunded proposals last year that were rated excellent.

Senator ENSIGN. Right.

Dr. PIETRAFESA. And, that, I consider to be a tragedy for this Nation. And, as I said in my testimony, we lost a member of the National Academy to an Asian university because he isn't willing to

spend the time to write ten proposals to get funded one time. And I consider that to really be tragic.

Again, on the ocean and atmospheric sciences side, kids love the ocean, they love the atmosphere; they're science geeks. And we could capitalize on this through education at the K–12 levels, and then entrain them into the physical and mathematical sciences through aggressive education. And so, I really do deeply believe, and the community believes, that we are undercapitalized in basic research, broadly defined, but certainly in the physical sciences and the mathematical sciences, including ocean and atmospheric sciences.

Thank you.

Senator ENSIGN. Mr. Ritter, I'd like to ask you, being from the private-sector, can you comment on what Wall Street would do if companies like yourselves started spending a lot of money on research that may take 20 years—basic research, this foundational research that we've been talking about? I mean, it is important to have for the record.

Mr. RITTER. Yes. Well, the investment community is looking for a fast return on investment on any expenditure that we make. And to the degree those expenditures aren't going to return revenue to the company with the placement in the market of products that our customers want, we're not going to get rewarded for doing long-term research.

Yes, we have a—we have an internal metric that we use, in terms of looking at our own research spending, and it's called R&D efficiency. I mean, we spend, you know, as I mentioned, \$2 billion a year on research. But how quickly and over what time line does that research expenditure translate into revenue? And that's what we're measured on by Wall Street. I mean, we like—we'd wish they were more forward-looking and long-term in their approach, but the reality is that they're not.

Senator ENSIGN. Very good.

You know, it's interesting, a question we should always ask. I have this little document. It's called the Constitution. And I always like to say, "What we're doing here, is it Constitutional?" And I just want to make sure that everybody understands that what we are doing helps to "To promote the progress of science," Article I, Section 8 of the Constitution mentions science in the context of patents. And I think that our founders, you know, recognized that there were certain things that should be handled by the Federal Government, and promoting the progress of science is built right into the Constitution. Even as a fiscal conservative who believes in market forces, for those who believe in market forces, OK, market forces can't apply to basic research. Market forces wouldn't allow basic research, in the general sense, as our economy is set up. And that's why it's so critical that we recognize the valuable role that the Federal Government can and should play here.

What the right amount of funding is, is very difficult to determine. You know, you could put \$200 billion to support basic research, and some would say that's not enough. And it is always difficult, in setting these priorities. That's why we doubled the funding for NIH, and now we're proposing doubling the funding for NSF and increasing some of the support for these other agencies and

other programs out there. But it is difficult, as you all know, setting the priorities.

Mr. Ritter, you wanted to comment.

Mr. RITTER. Yes. While reciting the Constitution, how about the tenth amendment and what the states are doing in this area, too? Because, I'll tell you, there's a very robust discussion going on in several states about how to align, you know, higher education and research assets behind, you know, state economic development goals. And, you know, as industry is increasingly unable to spend for the long-term on research, you know, we're not only here with the Federal Government, but we're also working with the states and in industry collaborative efforts to create new research partnerships.

You know, a great example of that is the partnership that the semiconductor industry has created with the National Science Foundation in nanoelectronics research. And there are two, soon to be three, nanoelectronics research centers that'll be up and running—one in New York, one in California, and one in Texas—that will have a combination of Federal, state, and private-sector funding, doing advanced research. And so, you know, the States have an important role to play in this in providing, you know, facilities, faculty, and graduate students, you know, who can do the kind of research and compete for the sort of merit-based grants, which you're looking at funding in some of the Federal research programs that you're looking at.

Senator ENSIGN. Good.

I want to thank all of you. It's been a fascinating discussion. I guess we just got notice that we have a vote coming up in 5 minutes. And these kinds of discussions are very important. You can see why I like them better. Nobody else shows up. I get—

[Laughter.]

Senator ENSIGN.—to spend more time asking questions and having a discussion with you all. But your testimonies are all valuable as we go forward. We're hoping that we can get a bill. You know, some of us think that it should be a comprehensive innovation and competitiveness bill. I would love to see that. We don't know whether, in the current climate, we'll be able to do a comprehensive bill. But if we can't get a comprehensive bill, we're at least going to try to pick off what we can get done this year, and maybe pick up the rest of it next year. But it is an exciting process.

And, you know, the President takes a lot of criticism these days. One thing that I told him yesterday in our meeting, was that I was really pleased that he mentioned innovation and competitiveness in his State of the Union Address. Without Presidential vision, without leadership from the White House—he's the only one with a bully pulpit—it's just like Eisenhower, with *Sputnik*, he gave us that vision that we had to compete—and we talked yesterday about the President giving us that vision, calling on the American people. If we want to compete in this globalized economy, there's no question, we have to set some certain priorities for our country. And the President is the one who has to challenge us to do that. And I think that if he does that, we will be up to that challenge.

So, thank you all very much for your testimony. And, before we leave, I just want to recognize Susan McDonald. She is over here

to my right, retiring after 30 years of dedicated employment to the Senate.

Congratulations, Susan. You've done a great job. You've made all of our lives a lot better, and made a lot of these hearings over the years go a lot more smoothly. So, thank you. Thanks for your service.

[Applause.]

Senator ENSIGN. This hearing is adjourned.

[Whereupon, at 11:40 a.m., the hearing was adjourned.]

A P P E N D I X

PREPARED STATEMENT OF HON. DANIEL K. INOUE, U.S. SENATOR FROM HAWAII

Technological innovation is the lifeblood of U.S. economic growth and well-being, and basic research is at the core of this system.

The National Academies of Sciences describes basic research as the “seed corn” for innovation. In their report, *“Rising Above the Gathering Storm,”* they point out that this country is essentially eating its seed corn by failing to make the proper investments in basic research necessary to maintain a competitive edge. Federal support for all research and development (R&D) has fallen from 67 percent in 1964 down to less than 30 percent today.

Industry has increased its support for R&D. However, much of this support is for near-term development and not the long-term basic research that is so vital.

Industry has a great history of supporting basic research through venerable names such as Bell Labs and Xerox PARC. But today, Wall Street’s focus is on the near-term only, and shareholders do not reward companies for making significant investments in basic research.

This investment is essential for our long-term, economic competitiveness, and it is becoming clear that only the government can afford to support the kind of research that may not bear fruit for a decade or more. I would like to hear more from our witnesses today about how we can rectify the current situation and ensure that we are putting the country on the right path.

Finally, many of the current reports and proposed legislative initiatives fail to address oceanic research. The oceans cover 70 percent of the Earth’s surface and can be a source of numerous new technologies and innovations. We must not disregard this important resource.

PREPARED STATEMENT OF HON. JOHN D. ROCKEFELLER IV,
U.S. SENATOR FROM WEST VIRGINIA

I am delighted that the Subcommittee has taken up the subjects of basic research and competitiveness, and I regret that I cannot be present to take part in the discussion. There is no doubt that the choices we make now about investments in basic research, both the size and the nature of our investments, will be a major factor in American prosperity a generation from now.

The globalization of the world economy is a reality, an accelerating trend that we cannot stop. It is also a matter that we must address with some urgency. Where we can, we must take steps to protect American jobs. Where we cannot, we must work to mitigate the impacts on our workers, their families, and their communities. And we absolutely must work to assure that our children and future generations will have good jobs, by making certain that America is competitive in the global economy of the future.

It’s well established that basic research conducted at universities can stimulate strong regional economic development. Companies focusing on high technology products find it profitable to locate near major research universities where they have convenient access to faculty researchers and highly trained graduates. The regions known as Silicon Valley in California, Route 128 in Massachusetts, and Research Triangle in North Carolina, are perhaps the best-known examples, but it happens wherever there are strong research universities.

I’m concerned that, as we stimulate innovation through investments in basic research, we assure equal opportunity, and proactively draw upon the talent, creativity, and energy of all Americans.

Congress and the National Science Foundation have long recognized the importance of regional diversity in research funding. It’s explicit in the NSF charter: “. . . it shall be an objective of the Foundation to strengthen research and education in the sciences and engineering, including independent research by individuals,

throughout the United States, and to avoid undue concentration of such research and education.”

In 1988, Congress authorized NSF to establish the Experimental Program to Stimulate Competitive Research (EPSCoR), to help universities in states that receive a very small share of NSF funding improve their competitiveness in research. Indeed, through the EPSCoR Program, the research capabilities of many universities have been improved. I strongly support the EPSCoR program’s focus to enhance research capacity which is done through the Research Infrastructure Improvement Grants. However, the geographic distribution of NSF research grants is still highly uneven.

Currently, 60 percent of NSF funding goes to institutions in just 10 states and 91 percent goes to institutions in 26 states. The remaining 9 percent is distributed in the remaining 24 states plus the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. The 27 jurisdictions that together receive only 9 percent of NSF funding are home to 19 percent of the U.S. population, 20 percent of the top two categories of research universities (by Carnegie Foundation ratings), 15 percent of employed scientists and engineers, and 14 percent of graduate students in science and engineering. And they are home to a large portion of Minority Serving Institutions—minorities that have not yet participated proportionately in the development of the American science and technology enterprise.

I also believe that NSF’s investments in education are essential. It is vital for our Nation to improve the quality of education, and to evaluate programs and teaching methods to learn what really works. I was proud to be a sponsor of the Math and Science Partnership (MSP) program a year ago, and I believe it shows promise and deserves additional funding.

I am sure than many of my colleagues on this Subcommittee will agree with me that we must do better. Eleven of us, both Republicans and Democrats, represent states that receive a very low percentage of NSF grants. Others cannot get an MSP grant due to funding limitations. It’s an issue of equal opportunity. But it’s also in the broad national interest that we enlist as many Americans as we can into the cause of assuring prosperity for future generations.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. DANIEL K. INOUE TO
DR. ARDEN L. BEMENT, JR.

Question 1. The Advanced Technology Solar Telescope (ATST) is slated to be built on Haleakala. Using adaptive optics technology, ATST will be able to provide the sharpest views ever taken of the solar surface. The National Science Foundation (NSF) has declared the project in “readiness.” However, the Foundation has instituted new processes for selecting Major Research Equipment and Facilities Construction (MREFC) projects. ATST is the first project living under the new rules.

In order to be on the “approved” list and be budgeted for construction funding, a project must have all of its environmental approvals and a firm cost for any intended mitigation. On the other hand, the shelf life of any environment impact statement (EIS) is limited, particularly with regard to the location of flora and fauna. If too much time elapses between the issuance of the EIS and the initiation of construction, some fear that the EIS may have to be redone. In addition, it is difficult to get community buy-in for a project when construction funds seem elusive or far off. There had been some talk of the potential for ATST to be included in the FY 2008 budget, but we now have indications that it will be included in FY 2009, at the earliest.

Can you tell me when the Advanced Technology Solar Telescope (ATST) can be included in the Foundation’s Major Research Equipment and Facilities Construction budget?

Answer. In order to be included in the Foundation’s Major Research Equipment and Facilities Construction budget, ATST must successfully pass two milestones:

1. The preparation of the necessary environmental impact statement as well as the required consultations under Section 106 of the National Historic Preservation Act.
2. An extensive review of cost, schedule, and management that will be carried out in October 2006, in order to establish the baseline budget and schedule.

Provided that the review is satisfactory, this schedule would support a possible decision by the National Science Board to include ATST in the Foundation’s FY 2009 budget request.

Question 2. Can you assure me that you will work with the ATST advocates to ensure that the new requirements for Major Research Equipment and Facilities

Construction project development and funding are realistic and allow projects to move forward in a timely manner?

Answer. NSF can give you that assurance. Indeed, representatives of ATST, the Division of Astronomical Sciences, and the Office of the Deputy Director for Large Facility Projects have already met to discuss the necessary steps and resultant time scales that must be completed before ATST can be included in an NSF budget request. The Division of Astronomical Sciences and the Office of the Deputy Director for Large Facility Projects are working closely together to plan the upcoming baseline review of ATST in order that the requirements are fully understood and the project can be well prepared for the review.

Environmental Management

Question 3. In late January, OMS announced a new scorecard to be applied to Federal agencies that would evaluate, among other things, their environmental management systems. Though in the past, NSF has funded primarily scientific research projects with few environmental impacts, there are now more than 25 projects on the various Major Research Equipment and Facilities Construction priority lists, most of which involve construction or activities that would likely impact the human environment. Moreover, before most of these projects can move forward, the agency will have to demonstrate compliance with all requisite environmental, biological, and historical laws or risk litigation and millions of dollars in cost overruns.

Has NSF's infrastructure and facilities planning capabilities advanced sufficiently to manage these increased environmental management and compliance issues?

Answer. As is the case with ATST, the Foundation uses program and support staff to ensure sufficient consideration of environmental issues. Whenever a large facility project is suitably advanced for consideration and possible funding, NSF assigns a program officer to support project-specific environmental requirements through the NSF grants and cooperative agreements process. The Office of the Deputy Director for Large Facility Projects and the Office of the General Counsel work closely with program officers to ensure proper identification and management of environmental issues. NSF's Grant Policy Manual, the particular terms of a solicitation or announcement, and the various documents that inform the oversight and management of a large facility all support the Foundation's management of environmental issues. The Foundation's experience has been that its processes and infrastructure provide sufficient opportunity for responsible management of environmental issues.

Question 4. Do you need additional legislative authority to build dedicated environmental management expertise at NSF? If not, how to you intend to build that expertise?

Answer. NSF has broad legislative authority pursuant to its organic act "to do all things necessary to carry out the provisions of this chapter [to initiate and support basic scientific research and programs]." 42 U.S.C. § 1870. Accordingly, NSF would not need additional legislative authority to further strengthen environmental management at the Foundation.

NSF recognizes that environmental considerations are an important part of planning for many large facility projects. NSF has staff with specialized expertise in this area within the Office of General Counsel and in some Directorates. NSF also recognizes that the demand for this expertise is likely to expand as a number of large facility projects advance into more mature stages of pre-construction planning. This is especially true for those Earth-observing systems that will consist of widely distributed infrastructure at multiple locations.

Development of New, Very Large Projects

Question 5. Last year, a provision was included in the National Aeronautics and Space Administration (NASA) Authorization bill to examine the problem of designing very large projects, including consideration of allowing funding for some planning and design work to come from the MREFC account rather than the research account.

What is the status of that review? How can we make sure that the design of new facilities does not overwhelm the capacity of the Science Directorates?

Answer. The NASA authorization addresses two pertinent items: (1) "Senior Review" of the facilities portfolio within the Division of Astronomical Science, and (2) design and development for Major Research Equipment and Facilities Construction (MREFC) projects, including a provision to consider alternative funding sources.

Item one, the Senior Review, is being conducted under the auspices of the Directorate for Mathematical and Physical Sciences. The final report is expected to be issued shortly. Item two, planning for very large projects, has been considered by the Foundation. The Office of the Deputy Director for Large Facility Projects re-

cently published *Guidelines for Planning and Managing the Major Research Equipment and Facilities Construction Account*, which outlines the pre-construction planning and development process. NSF's position is that funding for pre-construction planning of MREFC candidate projects should not be provided within the MREFC account. While the Foundation recognizes that the resources needed are very large, from five to as much as twenty-five percent of total construction/acquisition costs, NSF does not use MREFC funding to support these activities for several reasons:

- Annual operations and maintenance (O&M) costs for major facilities, once constructed, usually range from ten to twenty percent of the total construction cost. The annual outlay for operations and maintenance is roughly equivalent to the annual outlay for pre-construction planning. O&M budgets are funded from the Research and Related Activities (R&RA) Account. Over the 20–30 year typical operational lifetime of a facility, cumulative O&M expenditures represent a much larger total outlay than the construction funding, and one that competes directly with the pool of funds available to individual investigators in that discipline. Having these activities funded from R&RA ensures the backing of stakeholders. The research community served by the proposed facility must strongly support the facility throughout its various life-cycle phases and endorse the balance between the support of infrastructure and support for researchers using that infrastructure. NSF funds pre-construction activities within the R&RA account to retain pressure on the Directorates to propose no more facilities than they can afford to study and operate.
- Facilities ultimately proposed for construction funding are the result of a very long process of review by the supporting research community and NSF. This includes: peer review of the candidate project's scientific merit; NSF's ranking and relative prioritization of the project within its discipline and across disciplines served by NSF; and a thorough assessment of its relative importance to the Nation in comparison to other opportunities and national needs. This multi-step process involves progressive levels of scrutiny as the project definition matures. At any stage of review a project may be rejected, and many are. Assessment must be objective, based on expert review and peer judgment. Including specific projects in the MREFC budget at early stages of planning, before this objective judgment can be fully applied, would give them stature prematurely and would compromise this careful review process.
- Large facilities built by NSF almost always involve interagency and international partnerships. It is important to send the right messages to these partners regarding NSF's intentions, so that the tentative nature of investment in pre-construction planning activities is fully understood. MREFC funding for pre-construction planning may appear to give unintended "standing" to a project that may not progress to late-stage planning.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV
TO DR. ARDEN L. BEMENT, JR.

Question 1. How well is NSF performing in its mandate to assure that it avoids undue concentration in research funding? Please provide the Subcommittee with data showing how the geographic distribution of research funding has changed over the past several years.

Answer. As noted in its mission statement, the NSF EPSCoR program is designed to assist the Foundation in its statutory function to strengthen research and education in science and engineering throughout the U.S. and to avoid undue concentration of such research and education. Therefore, broadening participation is a major objective for NSF EPSCoR and its investment portfolio is structured to enhance the competitiveness of EPSCoR jurisdictions for NSF's spectrum of regular research funding. The regression line on *Figure 1* demonstrates that the initial 22 EPSCoR jurisdictions (AL, AK, AR, HI, ID, KS, KY, LA, ME, MS, MT, NE, NV, NM, NO, OK, PR, SC, SO, VT, WV, and WY that have participated in EPSCoR for at least 5 years) increased their aggregate percentage of NSF research support funds from approximately 5.1 percent in FY 1980 to 6.9 percent in FY 2005. This increase verifies that modest progress has occurred in the ability of the initial 22 EPSCoR participants to compete for merit-based research support from NSF.

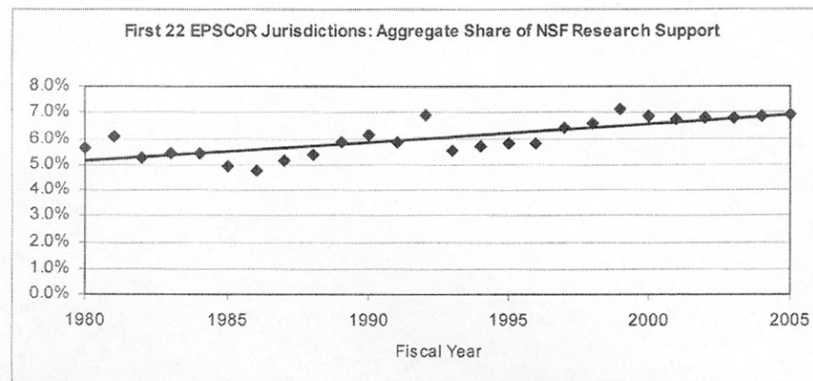


Figure 1

Figure 2 shows a similar graph for all the current 27 EPSCoR jurisdictions (the preceding 22 plus U.S.-VI, DE, NH, RI, and TN that were added during the FY 2002–2004 period). The regression line on this latter graph illustrates that the aggregate percentage of NSF research support funds awarded to the 27 EPSCoR jurisdictions went from approximately 7.6 percent in FY 1980 to 9.2 percent in FY 2005. Another measure of EPSCoR's impact is the positive trend in the total annual amount of NSF research support funds awarded to EPSCoR jurisdictions during the past 6 years. The amount of this NSF funding has increased from \$273 million in FY 2000 to \$383 million in FY 2005. Such data reveal that the EPSCoR strategy has indeed improved the geographic distribution of NSF's research funding.

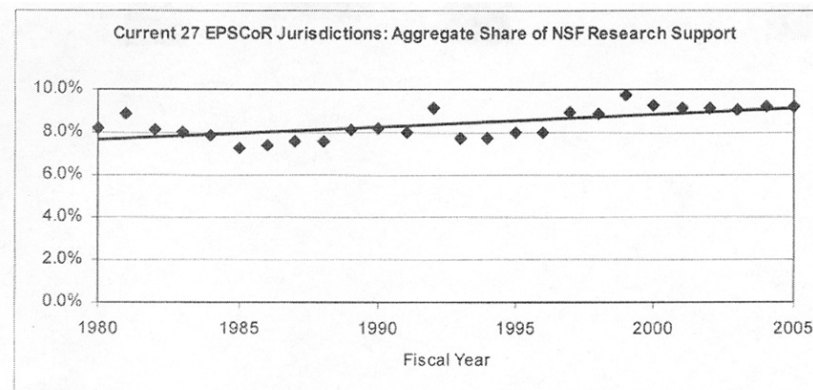


Figure 2

Question 2. The President's Budget for FY 2007 proposes a smaller increase for the NSF EPSCoR program than for the total NSF budget. I believe that the NSF EPSCoR budget should increase proportionally with the total budget to meet the basic goal of not leaving the EPSCoR states behind. What do you think and how can we meet geographic diversity goals without increasing EPSCoR?

Answer. The EPSCoR budget is small relative to the overall NSF budget and is used primarily to support investment elements that stimulate an increased research/education capacity in EPSCoR jurisdictions through: (1) awards to advance research infrastructure, both physical and human resources, in focused areas; (2) support for outreach activities to further acquaint the EPSCoR community with NSF opportunities, priorities, policies, and people; and (3) co-funding of meritorious proposals submitted from EPSCoR investigators to other NSF programs that are recommended for funding by the peer review process but for which there are insufficient funds for an award without joint support from EPSCoR. The awards co-funded by EPSCoR often involve young or new faculty members, members of underrepresented groups, graduate and undergraduate students, private-sector partnerships,

and cross-disciplinary projects. The infrastructure awards are sufficient to “initiate” the development of new scientific capacity (research equipment, start-up packages for attracting new faculty, competitive stipends for recruiting talented graduate students and post-docs, etc.). The jurisdictions are aware that EPSCoR investments should lead to other sources of significant funding to fully develop the assets needed for increased capacity, competitiveness, and project sustainability.

One measure of competitiveness of EPSCoR participants is the absolute difference between overall NSF and EPSCoR funding rates for proposals submitted to the Foundation’s research support programs. *Figure 3* shows a plot of these absolute differences in success rates for the FY 1996 through FY 2005 period. As shown, the success rate difference was approximately 8 percent in FY 1996 (27 percent for all NSF proposals compared to 19 percent for EPSCoR-based proposals) but decreased to about 4 percent in FY 2003 (24 percent for all NSF proposals compared to 20 percent for EPSCoR-based proposals), and has stayed near this 4 percent delta value since FY 2003. This “closing-of-the-gap” in funding rates for proposals submitted from EPSCoR jurisdictions is largely due to the successful EPSCoR co-funding and infrastructure improvement programs.

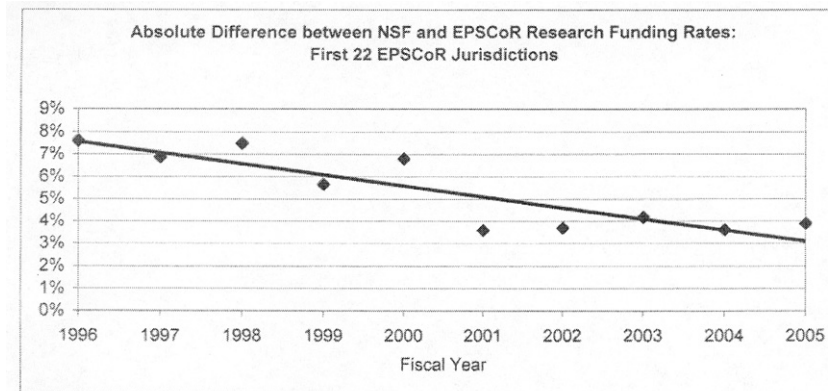


Figure 3

Question 3. The primary strategy of the NSF EPSCoR program has been to invest in the research infrastructure of states that receive very small portions of NSF funding. Do you agree that competitive grants for research infrastructure should continue to be the principal tool used by EPSCoR to enhance regional research competitiveness?

Answer. Please see the next response.

Question 4. What improvements would you recommend for the EPSCoR program, and will you be sure to consult with the stakeholders and Congress on any major changes?

Answer. Investment in critical research infrastructure is a productive and essential tool for enhancing the research capacity and competitiveness of EPSCoR jurisdictions. The evolving EPSCoR investment portfolio has yielded definite gains during the past years as evidenced by the trend lines in *Figures 1* through *3*. However, these gains appear to have leveled-off during the recent FY 2001–2005 period. Such indicators suggest it is now prudent to think about the optimum investment strategy for catalyzing further progress by the EPSCoR jurisdictions during the next 10–15 years. Therefore, NSF is organizing a community workshop entitled *EPSCoR 2020* to obtain broad, expert input on the goals, objectives, and investment strategies that will help define the future EPSCoR program at NSF. A proposal to develop and conduct this workshop event has been submitted to NSF by the University of South Carolina. The workshop, scheduled for June 15–16, 2006, will bring together key representatives from both the EPSCoR and non-EPSCoR communities to discuss and develop an updated vision for the NSF EPSCoR program. Such a strategic planning exercise is timely because of the essential contributions that EPSCoR-based scientists, engineers, teachers, and students can make to the American Competitiveness Initiative. NSF and its EPSCoR Office look forward to the opportunity of obtaining further input from our multiple stakeholders and their concomitant recommendations for *EPSCoR 2020*. Potential changes in the EPSCoR program as a

consequence of our attentive consideration of these recommendations will be discussed with stakeholders and Congress.

Math and Science Partnership Program

Question 5. Can you provide more information about the promise of the MSP program, and what NSF could do to enhance education if Congress provided the amount of money authorized for the program which is \$200 million?

Answer. America's students have significant aspirations for their own education. More than 90 percent of the Nation's high school seniors plan to attend college, including two-year colleges, and approximately 70 percent of graduates actually do go on to college within 2 years of their graduation [Education Trust, 1999]. Yet, the middle and high school years foster a leaky pipeline in science, technology, engineering, and mathematics (STEM) education that falls short in supporting student aspirations and therefore requires special attention.

NSF's Math and Science Partnership (MSP) program has yielded some promising findings for students, for teachers, and with newly developed tools and instruments. NSF's MSP has focused on building human and institutional capacity to engage in K-12 STEM education, especially in the Nation's institutions of higher education. Approximately 1,200 faculty and administrators have documented their participation to date. Of these, 69 percent are STEM disciplinary faculty and 67 percent are tenured or on a tenure-track. Additionally, 30 percent report "no prior experience" in K-12 reform. To further build and sustain the capacity of the Nation's STEM disciplinary faculty for educational work, the new MSP solicitation (NSF 06-539) calls for proposals that engage the national disciplinary/professional societies. MSP is also building human capacity to engage in high-quality evaluation (*e.g.*, evaluation-focused projects at Utah State University, University of Wisconsin—Madison). *Evidence: An Essential Tool—Planning for and Gathering Evidence using the Design-Implementation-Outcomes (DIO) Cycle of Evidence* (NSF 05-31) is an example of an MSP product for guiding project-level evaluation.

MSP has contributed to sustainability through the development of tools and instruments that did not exist previously, including a number of such resources being extensively used in the Department of Education's MSP sites in the states. Examples include tools that assess teachers' growth in content knowledge in mathematics (University of Michigan) and the sciences (Horizon Research & AAAS for one project, Harvard University for another), that address student motivation (University of Michigan) and that evaluate STEM education partnerships (Georgia Institute of Technology).

MSP work has changed teacher education. In a first analysis of a sample of 10 Partnerships, over 100 college courses have been redesigned or newly developed with MSP support. Most new courses are packaged within existing, formalized programs or as part of new pre-service programs. Most are also aligned with state standards and external disciplinary recommendations. Every Partnership in the sample has developed new programs, certificate pathways or degrees.

NSF looks forward to applying these and other findings to support the important work of the Department of Education's MSP program.

